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THE GREAT DROUGHT OF 1893,

AND ITS ATTENDANT METEOROLOGICAL PHENOMENA.

By FREDERICK J. BRODIE, F.R.Met.Soc.

[Received October 16th.—Read November 15th, 1893.]

THE drought which prevailed over England and the neighbouring parts of the Continent during the spring and early summer of 1893 was so exceptional, both as regards severity and duration, that little apology is needed for submitting the main facts of the case to the notice of the Society on this, the earliest available, opportunity. The drought itself was followed, after a long showery interval in July, by another spell of fine weather in August and September, so that one was at first tempted to extend the limits of the present inquiry up to Michaelmas. On reflection, however, it seemed quite evident that a wide distinction must be drawn between a drought and a mere deficiency of rain; and as the former characteristic ended with the close of June it was decided to confine this investigation to the weather of the four months commencing with March. July was decidedly unsettled, especially in the extreme south of England, where the rainfall was in many places con-

siderably in excess of the average, and notwithstanding all the subsequent fine weather there was nothing worthy of the name of a drought either in August or September.

The various elements which go to make up what we call "the weather" are so intimately connected, that it is impossible for one feature to distinguish itself in any abnormal manner without the others being also affected to a greater or less extent. The truth of this was abundantly shown during the period under discussion; for if the absence of rain was phenomenal, the conditions shown by the barometer, the thermometer, and the sunshine recorder were in many ways no less remarkable. Barometric pressure was, as one would naturally expect, greatly in excess of the average; temperature was also high, with a large amount of diurnal range; and the duration of sunshine was in many places the longest on record.

Barometric Pressure.

In endeavouring to trace the origin of the drought one can scarcely fail to be impressed with a sense of the inadequacy of our knowledge respecting the causes which lead even to the greater and more widespread of our climatic variations. We may say, as we do in the present case, that the general character of the weather is governed by the pressure distribution, but here we must stop. Any attempt to go further and to discover what it is that leads to the formation of the cyclones and the anticyclones lands us at once in a debatable region from which the mists of theory have not yet rolled away. For the present it is sufficient to state that the great drought of 1893 was due, so far as can be seen, to the almost constant prevalence of large anticyclonic systems. During the four months under discussion no fewer than eight such areas were observed over a large portion of the United Kingdom, their aggregate duration extending over 77 days out of the 122 comprised within the four months' record. In addition to these cases there were several other instances in which the southern portions of the Kingdom only were influenced by anticyclones which spread over from the Continent. At times the distribution of pressure over our Islands became cyclonic, the depressions advancing in most cases from the northward, but even when this change occurred the tendency for fine dry weather was so pronounced that the showers experienced were very local, and in some places exceedingly slight. On one or two occasions the presence of a definite depression over our southern counties was altogether unattended by rain, or indeed by any unsettled appearance of the sky. The leading characteristics of the several anticyclones are shown in the following notes, together with a few facts respecting the intervals of cyclonic weather which occurred between each high pressure system.

No. I. March 5-10. An anticyclone of moderate size spread over our Islands from the westward on March 5th. The central portion of the system remained off our south-west coasts until the 10th, when the entire area moved away in a south-easterly direction to the Mediterranean. During its prevalence the wind over our Islands varied between West and North-west; temperature was high generally, but the nights cold; the weather was very dry in all but our extreme northern and north-western districts.

MARCH 11-16. Some depressions hitherto observed in the far north now spread over us. Westerly and South-westerly winds therefore set in generally, with lower temperatures and with showers in all districts. Snow or sleet was fairly general on the 16th and 17th.

No. II. MARCH 18-29. This system advanced over our Islands from the Atlantic on March 18th, and was at first of moderate size, but gradually extended in all directions until it finally embraced nearly the whole of Europe. The central area lay at first directly over the United Kingdom, whence it moved eastwards to the Netherlands and north-eastwards to Scandinavia, the latter country being reached on the 24th. Between the 27th and 29th the system moved southwards to central Europe, where it partially dispersed. The winds over the United Kingdom were at first very variable, then Easterly; temperature was high in the daytime, but very low at night; the weather was fine and dry generally.

MARCH 30-APRIL 1. Shallow depressions in the far north spread southwards, and Westerly and South-westerly winds again set in, with showers in all but our eastern and southern districts, where the weather remained exceedingly dry.

No. III. APRIL 1-14. On April 1st two anticyclonic areas appeared,—one over Russia and the other off our south-west coasts. The systems afterwards increased in size until they formed one large anticyclone, which spread over the whole of Europe by April 5th. After the 9th depressions began to advance over the north of Scandinavia from the westward, and the anticyclone, which had already undergone several modifications in form, moved slowly southwards. By the 15th its influence had practically disappeared from north-western Europe. The winds over our Islands, which were at first variable, finally became Easterly. Temperature exhibited great fluctuations, but was mostly above the average, sharp night frosts being experienced, however, in all the inland districts. The weather was fine and bright excepting in the extreme north, and even there the rainfall was below the normal.

APRIL 15-16. Shallow depressions appeared first in the north and afterwards in the west, and showers fell in all the more western and northern parts of the Kingdom.

No. IV. APRIL 17-28. An anticyclone formed over the North Sea on April 17th, and gradually spread over a considerable portion of the Continent. After the 24th depressions appeared over France and Spain, and the southern portion of the high pressure system gave way. The weather over our Islands remained, however, under its influence until the 28th, when the anticyclone apparently moved away to the Atlantic. During its prevalence the winds, though rather variable, were mostly from some Easterly quarter. Temperature was very high, especially on the 19th and 20th, when the thermometer rose to above 80° in many parts of England. The weather was very fine over England and Ireland, but gradually became unsettled in Scotland.

APRIL 29-MAY 2. A depression first spread south-eastwards from our northern coasts across the North Sea, and North-westerly winds with showery weather set in generally. On May 2nd another disturbance passed northwards along the Irish and Scotch coasts. Decided falls of rain were experienced in the western and northern parts of the United Kingdom, but in the south-eastern districts the rainfall was slight and very local.

No. V. MAY 3-13. On May 3rd the barometer rose generally, and a large anticyclone was quickly formed over the whole of Europe, its central area being located for the most part over the northern countries. After the 10th the system became reduced in size, owing to the appearance of depressions in the far northern and also in the southern portions of Europe. On the 14th the remaining portion of the anticyclone, which had by this time settled down over the more central countries, gradually dispersed. During its prevalence the winds in our Islands were mostly Easterly; temperature was high, though less so than it had been with anticyclone No. IV.; and the weather was fine and dry in all but the extreme northern and north-western districts.

A rather long period of unsettled weather now ensued, during which a series of depressions travelled northward along our western coasts, their secondaries in many instances advancing directly over the United Kingdom. Southerly (South-east to South-west) winds prevailed generally, temperature remained high with warmer nights than had been experienced for a long time past; and rainfall, though varying greatly in different localities, was fairly abundant in all but the eastern and southern parts of the Kingdom.

No. VI. MAY 25-JUNE 1. The sixth anticyclone advanced from the Atlantic on May 25th, and soon spread eastwards over the entire Kingdom, lasting till June 1st. The central portion remained for the most part off our western coasts, and the prevailing winds were, therefore, North-westerly or Northerly. Temperature fell generally, but did not sink much below the normal; the weather was rather showery, with thunderstorms in many places.

On June 2nd and 3rd a depression passed along our western coasts occasioning further showers in most parts of the Kingdom. In the east and south of England, however, the rainfall was slight and very local.

No. VII. JUNE 4-12. This system spread over our Islands from the southward on June 4th, and gradually increased in size until it covered the greater part of Europe. After the 10th, however, its area became greatly diminished, and between the 12th and 15th it almost entirely dispersed over Scandinavia. The winds, although rather variable in the north of our Islands, were mostly from the Eastward; temperature was high, and, with the exception of one or two local falls of rain of considerable amount (due to thunderstorms), the weather was again fine and dry.

On the 13th and 14th a complex area of low pressure spread over us from the southward, but with the exception of a few local thunderstorms the weather was not materially affected.

No. VIII. JUNE 15-19. A general rise of the barometer took place on June 15th and 16th, and a large anticyclone was soon developed over our Islands and the greater part of the Continent. After the 17th, however, when depressions spread over northern and eastern Europe from the northward, the system became reduced in size and gradually passed away over the Atlantic. During its prevalence in our neighbourhood light variable winds were general; temperature was exceedingly high, maxima varying between 85° and 90° being registered in many parts of Great Britain. The weather was very fine until the 19th, when smart thunderstorms occurred in the south and south-east of England.

The remainder of June was unsettled and showery, with a temperature differing but little from the normal. On the 22nd and 23rd a well marked depression advanced in a south-south-easterly direction over the northern and eastern parts of Great Britain and occasioned cool Northerly and North-westerly winds in all districts, while from the 26th to 29th the weather was influenced by some rather large disturbances which travelled across the more northern parts of our Islands from the Atlantic. Quite at the close of the month another large anticyclone was again developed over western Europe and remained under observation during the early days of July.

One of the most important features in connection with the anticyclones whose career we have briefly sketched was the remarkable manner in which they developed from areas of moderate size into huge systems which frequently embraced the whole of Europe. The source whence the feeding power was derived suggests questions of the highest interest, for it is quite certain that if the causes which lead to the formation and movements of anticyclones were clearly understood, we should have a very important key to the whole chain of events governing our weather changes. The effect of so much anticyclonic weather on the instrumental records is shown in Table

I., which gives for 30 stations, situated in various parts of the British Islands, the mean barometric pressure for each of the four months, and also for the period as a whole, with its difference from the average for the 20 years 1871-90. The values are compiled from observations made at 8 a.m. only, but experience shows that the mean pressure at that hour differs very slightly from that derived from 24 hourly readings. It will be seen that there was in each month an excess of pressure in all parts of the Kingdom.

TABLE I.—MEAN BAROMETRICAL PRESSURE AT 8 A.M., MARCH TO JUNE, 1893.

Stations.	March.		April.		May.		June.		The Entire Period.	
	Mean Pressure.	Diff. from Average.	Mean Pressure.	Diff. from Average.	Mean Pressure.	Diff. from Average.	Mean Pressure.	Diff. from Average.	Mean Pressure.	Diff. from Average.
	Ins.	In. +	Ins.	In. +	Ins.	In. +	Ins.	In. +	Ins.	In. +
SCOTLAND, N.										
Sumburgh Head	29·776	·025	30·083	·243	30·014	·135	29·942	·059	29·954	·116
Wick	29·845	·052	30·111	·263	30·010	·109	29·972	·074	29·985	·125
Stornoway	29·869	·091	30·109	·285	29·972	·086	29·952	·076	29·976	·135
SCOTLAND, E.										
Nairn	29·898	·088	30·128	·280	30·001	·093	29·960	·056	29·997	·129
Aberdeen	29·937	·112	30·174	·316	30·045	·127	29·980	·064	30·034	·155
Leith	29·984	·131	30·179	·316	30·036	·104	29·972	·042	30·043	·148
ENGLAND, N.E.										
Shields	30·015	·135	30·195	·329	30·057	·114	29·983	·035	30·063	·154
York	30·066	·158	30·207	·332	30·074	·112	30·007	·038	30·089	·160
Spurn Head	30·050	·154	30·187	·324	30·059	·103	29·987	·023	30·071	·151
ENGLAND, E.										
Yarmouth	30·089	·169	30·180	·308	30·063	·096	30·003	·026	30·084	·150
Cambridge	30·136	·195	30·200	·320	30·082	·106	30·019	·034	30·109	·163
MIDLAND COUNTIES.										
Loughborough	30·119	·187	30·207	·328	30·081	·108	30·023	·043	30·108	·167
Oxford	30·149	·198	30·186	·302	30·079	·098	30·021	·035	30·109	·158
ENGLAND, S.										
London	30·148	·198	30·179	·301	30·079	·098	30·028	·036	30·109	·159
North Foreland	30·127	·197	30·153	·283	30·059	·089	29·997	·017	30·084	·146
Dungeness	30·131	·193	30·135	·271	30·054	·084	29·999	·017	30·080	·141
Hurst Castle	30·159	·205	30·148	·277	30·071	·089	30·023	·025	30·100	·149
SCOTLAND, W.										
Ardrossan	30·001	·136	30·160	·303	30·030	·095	29·972	·040	30·041	·144
ENGLAND, N.W.										
Liverpool	30·093	·182	30·187	·320	30·065	·104	30·002	·036	30·087	·161
Holyhead	30·080	·173	30·161	·304	30·049	·093	29·999	·033	30·072	·150
ENGLAND, S.W.										
Pembroke	30·121	·192	30·148	·296	30·047	·086	30·016	·042	30·083	·154
Prawle Point	30·152	·187	30·128	·252	30·065	·073	30·019	·012	30·091	·131
IRELAND, N.										
Malin Head	29·971	·106	30·143	·303	29·998	·073	29·981	·051	30·023	·133
Donaghadee	30·053	·171	30·182	·323	30·050	·103	29·998	·052	30·071	·162
Belmullet	30·032	·157	30·166	·331	30·011	·086	30·003	·068	30·053	·160
IRELAND, S.										
Parsonstown	30·075	·150	30·167	·303	30·029	·071	30·013	·041	30·071	·141
Valencia	30·106	·181	30·153	·299	30·022	·059	30·031	·056	30·078	·149
Roche's Point	30·109	·182	30·164	·313	30·038	·079	30·028	·055	30·085	·157
CHANNEL ISLANDS.										
Scilly	30·124	·177	30·096	·240	30·025	·051	30·014	·018	30·065	·122
Jersey	30·174	·213	30·107	·235	30·072	·083	30·029	·019	30·096	·138

In March the difference from the normal was slight in the north of Scotland, but considerable elsewhere, the greatest divergence being shown in the extreme

south of England, where the values were about 0·2 in. above the average. At Kew there have been only two years since 1870 (1874 and 1875) which had a higher mean pressure in March.

In April the excess of pressure was very much greater than in March, the difference from the normal amounting to more than three-tenths of an inch at a considerable number of the stations. At Kew the mean pressure in this month was the highest on record for April, though not much higher than that in 1870. The unusual height of the barometer was all the more remarkable when we remember that for some hitherto unexplained reason April has a lower mean pressure than any other month in the year.

In May the excess of pressure was very much less than in April and appreciably less than in March, the districts with the largest excess being the northern and eastern parts of Great Britain, where the values were more than a tenth of an inch above the average.

In June the excess was less marked even than in May, being less than five hundredths of an inch at most of the English stations, and less than two hundredths in the extreme south.

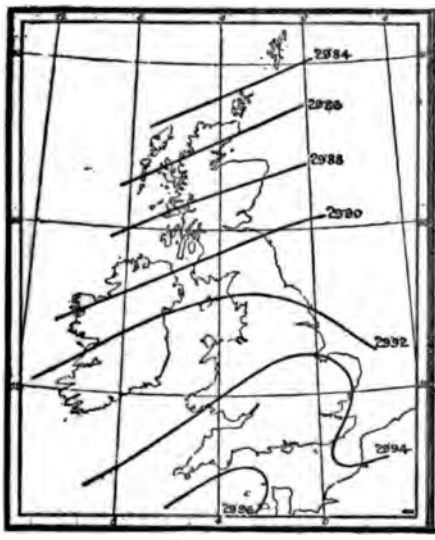


FIG. 1.
Average Distribution of Pressure, March to June, for the 20 years, 1871–90.

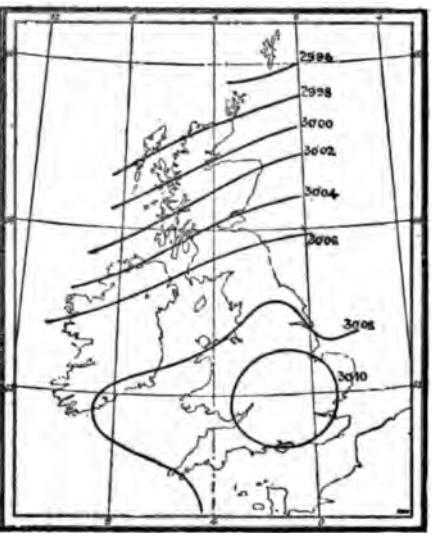


FIG. 2.
Distribution of Pressure, March to June, 1893.

Taking the period of four months as a whole, the mean values showed a large excess in all parts of the Kingdom, the difference from the normal being greatest (0·16 in. or more) over the central parts of England, and least (0·12 in. or less) in the extreme north of Scotland and also in the Scilly Islands. At Kew the mean for the entire period was higher than any observed during a similar time of the year since the year 1870. The general result for the four months is shown very clearly in Figs. 1 and 2, the isobars in which are drawn for every two hundredths of an inch. Fig. 1 represents the average

distribution based on values extending over the 20 years 1871-90, and Fig. 2 the distribution of mean pressure in 1893. With regard to the actual values, it will be seen that the line of highest pressure in the map of averages appears only as the line of lowest pressure in the chart for 1893, every isobar in the latter being of a far higher value. The general distribution of pressure shown by the two maps is also very different. In the average map there is a moderate gradient for South-westerly winds over the entire Kingdom, the tendency being cyclonic in the northern but anticyclonic in the southern districts. In the map for 1893 the South-westerly gradient is confined to the more northern parts of the Kingdom, where it is steeper than usual. Over England the distribution is decidedly anticyclonic.

Temperature.

The mean temperature was above the average for the 20 years 1871-90 in each of the four months, and in almost all parts of the Kingdom, the excess being upon the whole greatest in April and May, rather less in March, and considerably less in June. Taking the period as a whole, the mean temperature over England was about 4° above the average, but considerable local variations were observed, the difference from the normal being in some cases very little more than 2°, and in other places as much as 5°. To obtain a clearer conception of the abnormal temperatures of the period it is, however, necessary to analyse the records a little more closely, the mean values alone giving a very inadequate idea of the influence of the strong anticyclonic tendency which prevailed throughout the four months. In the winter time an anticyclone is accompanied, as most persons are aware, by cold weather, and in the summer time by warmth. In the spring and autumn the anticyclone brings us a combination of these two qualities, and so in the period under discussion we find that while the day temperatures were mostly very high, the nights were cold, with frequent sharp frosts in the inland districts. The effect of these conflicting influences is shown very clearly in Table II., where the means of the maximum and minimum readings taken at a number of stations situated in various parts of England are compared with the average for the 20 years 1871-90.

A careful examination of the table shows that the diurnal range was not very much in excess of the average in May or June, but that it was decidedly large in March, and still larger in April, when the anticyclonic conditions were most pronounced. The difference existing between the range of temperature in the inland districts as compared with that on the coast has seldom been more forcibly illustrated than in the period under review. Taking the month of April, for example, we find that at Cambridge the mean of the daily maxima was more than 11° in excess of the average, while the mean of the minima was 0°·7 below it. At Yarmouth, in the same district but on the coast, the maximum readings were only a degree above the average, while the minimum readings were also above the normal. The maximum readings at Cambridge were in fact as much as 17° higher than those at Yarmouth, while the minima at the inland station were more than 4° lower than those on the coast. The

TABLE II.—MEAN TEMPERATURE AND MEAN MAXIMUM AND MINIMUM TEMPERATURES EXPERIENCED OVER VARIOUS PARTS OF ENGLAND, MARCH TO JUNE 1893, WITH THE MEAN DAILY RANGE, AND WITH DIFFERENCES FROM THE AVERAGE.

Stations.	March.								April.								May.			
	Mean Temperature.		Daily Maxima.		Daily Minima.		Mean Daily Range.		Mean Temperature.		Daily Maxima.		Daily Minima.		Mean Daily Range.		Mean Temperature.		Daily Maxima.	
	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.
ENGLAND, N.E.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Durham	44·4	+4·3	53·8	+7·1	35·0	+1·6	18·8	+5·5	46·8	+2·9	57·0	+ 5·4	36·5	+0·3	20·5	+ 5·1	52·8	+4·1	62·2	+5·1
Scarborough ..	44·4	+3·4	51·3	+5·3	37·4	+1·4	13·9	+3·9	45·2	+0·6	51·5	+ 2·0	38·8	—0·8	12·7	+ 2·8	52·0	+2·5	58·1	+2·8
York	45·1	+4·0	55·7	+7·6	34·5	+0·5	21·2	+7·1	49·6	+4·0	61·6	+ 8·1	37·6	—0·1	24·0	+ 8·2	54·8	+3·9	64·5	+4·9
ENGLAND, E.																				
Hillington.....	45·0	+3·6	56·0	+7·0	33·9	+0·2	22·1	+6·8	49·1	+3·2	60·8	+ 6·5	37·4	0·0	23·4	+ 6·5	54·6	+3·4	64·6	+3·9
Yarmouth.....	43·8	+3·7	49·7	+4·5	37·8	+2·9	11·9	+1·6	45·7	+1·2	50·3	+ 1·2	41·0	+1·1	9·3	+ 0·1	52·5	+2·3	57·6	+2·2
Cambridge	46·6	+5·0	59·5	+9·3	33·6	+0·6	25·9	+8·7	51·9	+5·3	67·2	+11·4	36·6	—0·7	30·6	+12·1	56·7	+4·7	68·8	+6·8
MID. COUNTIES.																				
Loughborough ..	45·8	+3·9	58·2	+8·7	33·4	—0·8	24·8	+9·5	50·6	+4·0	64·5	+ 9·4	36·7	—1·4	27·8	+10·8	55·5	+3·3	66·6	+4·9
Oxford	46·0	+4·0	57·1	+8·1	34·9	0·0	22·2	+8·1	51·8	+5·3	64·4	+10·4	39·1	+0·2	25·3	+10·2	56·6	+4·6	67·1	+6·5
ENGLAND, S.																				
London	46·3	+3·6	56·7	+6·7	35·9	+0·5	20·8	+6·2	52·8	+4·9	64·4	+ 8·4	41·2	+1·5	23·2	+ 6·9	57·8	+4·4	67·8	+5·5
Strathfield T. ..	45·5	+3·4	57·3	+7·1	33·6	—0·4	23·7	+7·5	51·5	+4·7	66·7	+10·7	36·2	—1·4	30·5	+12·1	56·2	+4·0	69·0	+6·4
Hastings (St. Leonard's)	46·6	+3·8	53·2	+4·7	39·9	+2·9	13·3	+1·8	52·1	+4·7	60·6	+ 6·9	43·6	+2·6	17·0	+ 4·3	55·4	+2·9	62·7	+3·0
ENGLAND, N.W.																				
Stonyhurst	44·0	+3·4	50·8	+3·9	37·1	+2·8	13·7	+1·1	49·0	+3·7	58·2	+ 5·3	39·7	+2·1	18·5	+ 3·2	53·4	+2·9	60·8	+2·0
Manchester	46·1	+5·1	54·3	+6·9	37·9	+3·4	16·4	+3·5	50·9	+5·4	61·0	+ 7·9	40·7	+2·9	20·3	+ 5·0	54·6	+4·3	62·7	+4·1
Holyhead	46·9	+3·8	52·4	+5·2	41·4	+2·5	11·0	+2·7	50·6	+3·9	56·6	+ 5·2	44·5	+2·5	12·1	+ 2·7	54·9	+3·7	60·7	+4·5
ENGLAND, S.W.																				
Pembroke	46·5	+3·6	50·4	+3·8	42·5	+3·4	7·9	+0·4	51·5	+5·3	57·4	+ 7·0	45·5	+3·6	11·9	+ 3·4	54·6	+4·1	59·6	+4·6
Cullompton	46·0	+3·4	56·2	+6·4	35·8	+0·5	20·4	+5·9	52·5	+6·1	65·2	+10·8	39·7	+1·4	25·5	+ 9·4	56·3	+4·9	66·3	+5·8
Plymouth	47·6	+3·4	54·5	+4·3	40·7	+2·6	13·8	+1·7	53·3	+4·9	61·1	+ 6·2	45·5	+3·7	15·6	+ 2·5	56·4	+2·8	62·9	+2·2

TABLE II.—MEAN TEMPERATURE AND MEAN MAXIMUM AND MINIMUM TEMPERATURES EXPERIENCED OVER VARIOUS PARTS OF ENGLAND, MARCH TO JUNE 1893, WITH THE MEAN DAILY RANGE, AND WITH DIFFERENCES FROM THE AVERAGE—*Continued.*

Stations.	May.				June.								The Entire Period.							
	Daily Minima.		Mean Daily Range.		Mean Temperature.		Daily Maxima.		Daily Minima.		Mean Daily Range.		Mean Temperature.		Daily Maxima.		Daily Minima.		Mean Daily Range.	
	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.	Mean.	Diff. from Average.
ENGLAND, N.E.	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
Durham.....	43·4	+3·1	18·8	+2·0	58·1	+2·3	67·1	+2·1	49·0	+2·5	18·1	−0·4	50·5	+3·4	60·0	+4·9	41·0	+1·9	19·0	+3·0
Scarborough....	45·8	+2·2	12·3	+0·6	56·9	+1·3	63·0	+1·6	50·7	+0·9	12·3	+0·7	49·6	+1·9	56·0	+2·9	43·2	+0·9	12·8	+2·0
York	45·1	+2·9	19·4	+2·0	59·3	+2·0	69·0	+2·9	49·5	+1·1	19·5	+1·8	52·2	+3·5	62·7	+5·9	41·7	+1·1	21·0	+4·8
ENGLAND, E.																				
Hillington.....	44·5	+2·9	20·1	+1·0	59·3	+1·6	69·9	+2·2	48·7	+1·1	21·2	+1·1	52·0	+3·0	62·8	+4·9	41·1	+1·0	21·7	+3·9
Yarmouth.....	47·4	+2·5	10·2	−0·3	57·0	+0·4	62·3	+0·3	51·6	+0·5	10·7	−0·2	49·8	+2·0	55·0	+2·1	44·5	+1·8	10·5	+0·3
Cambridge	44·6	+2·6	24·2	+4·2	61·3	+2·7	73·9	+5·3	48·7	+0·2	25·2	+5·1	54·2	+4·5	67·4	+8·2	40·9	+0·7	26·5	+7·5
MID. COUNTIES.																				
Loughborough..	44·4	+1·8	22·2	+3·1	60·2	+1·4	71·7	+3·1	48·6	−0·4	23·1	+3·5	53·1	+3·2	65·3	+6·6	40·8	−0·2	24·5	+6·8
Oxford	46·0	+2·6	21·1	+3·9	61·0	+2·8	71·5	+4·6	50·5	+1·0	21·0	+3·6	53·8	+4·1	65·0	+7·4	42·6	+0·9	22·4	+6·5
ENGLAND, S.																				
London	47·7	+3·3	20·1	+2·2	62·1	+2·2	72·7	+3·6	51·4	+0·8	21·3	+2·8	54·8	+3·8	65·4	+6·0	44·1	+1·6	21·3	+4·4
Strathfield T. ..	43·4	+1·7	25·6	+4·7	60·5	+2·0	73·2	+4·4	47·8	−0·3	25·4	+4·7	53·5	+3·6	66·6	+7·2	40·3	−0·1	26·3	+7·3
Hastings (St. Leonard's)	48·0	+2·7	14·7	+0·3	60·0	+1·7	67·5	+2·2	52·4	+1·1	15·1	+1·1	53·5	+3·2	61·0	+4·2	46·0	+2·3	15·0	+1·9
ENGLAND, N.W.																				
Stonyhurst	45·9	+3·8	14·9	−1·8	58·7	+2·2	66·9	+2·0	50·4	+2·4	16·5	−0·4	51·3	+3·1	59·2	+3·3	43·3	+2·8	15·9	+0·5
Manchester	46·4	+4·5	16·3	−0·4	59·3	+2·7	68·5	+3·4	50·1	+2·1	18·4	+1·3	52·7	+4·3	61·6	+5·5	43·8	+3·2	17·8	+2·3
Holyhead	49·1	+2·9	11·6	+1·6	58·8	+2·2	65·1	+3·5	52·4	+0·9	12·7	+2·6	52·8	+3·4	58·7	+4·6	46·9	+2·2	11·8	+2·4
ENGLAND, S.W.																				
Pembroke	49·6	+3·7	10·0	+0·9	59·3	+3·4	64·5	+4·2	54·0	+2·5	10·5	+1·7	53·0	+4·1	58·0	+4·9	47·9	+3·3	10·1	+1·6
Cullompton	46·3	+4·1	20·0	+1·7	60·5	+2·8	72·1	+5·2	48·8	+0·4	23·3	+4·8	53·9	+4·4	65·0	+7·1	42·7	+1·6	22·3	+5·5
Plymouth	49·8	+3·3	13·1	+1·1	60·7	+1·4	68·5	+2·4	52·8	+0·4	15·7	+2·0	54·5	+3·1	61·8	+3·8	47·2	+2·5	14·6	+1·3

mean daily range at Cambridge and also at Strathfield Turgiss for the month of April was over 30°, or more than 12° in excess of the average. At Yarmouth, however, the daily range was normal, and at the other coast stations it was not much above the average. The same feature is shown, though in a less marked degree, throughout the whole four months, the mean daily range for the entire period being exceedingly large—22° to 27°—in the midland counties and at most of the inland stations in the east and south of England, but comparatively small—10° to 15°—in nearly all localities in proximity to the sea.

Bright Sunshine.

The main facts relating to the sunshine of the period are given in Table III., which has been compiled from the records made at 48 stations situated in various parts of the United Kingdom. The table gives for each month and for the entire period, firstly, the number of hours of bright sunshine, with the difference from the average for the 10 years 1881-90, in all places for which such an average exists; secondly, the percentage of the possible duration; thirdly, the mean amount of sunshine per day; and fourthly, the number of days on which bright sunshine was entirely absent.

The figures show that in March the amount recorded was in excess of the average at all stations excepting those in the west of Ireland and the north of Scotland, the excess being large in almost all the English districts, and greatest of all in the midland counties. The percentage of the possible duration was above 50 at nearly all the eastern, central, and southern stations, while in the Channel Islands it exceeded 60. The number of sunless days was smallest in the midland counties, where three stations out of five reported only one such occasion.

In April the total number of hours recorded was above the average in all districts, the excess being somewhat small in Ireland and Scotland, but very large over England, and especially so in the eastern, midland, and southern districts. In the regions last mentioned the percentage of the possible amount was considerably over 60, and in the Channel Islands it ranged between 71 and 72, while at Westbourne it rose to 74. At the Channel stations generally the mean daily amount of sunshine in April exceeded 9 hours, the highest proportion of all being at Westbourne, where the sun shone brightly for an average of more than 10 hours per day. Less than two sunless days were recorded over a considerable portion of England, and at the Channel stations there were none at all.

May was decidedly less sunny than either March or April, the total number of hours recorded being below the average in Ireland, Scotland, and the north of England, and not very much above the normal even in the southern parts of the Kingdom. Over England generally the percentage of the possible duration was below 50, and in the more northern districts it was mostly below 40. At some of the Channel stations, however, there was more than half the possible amount, while at Guernsey and Jersey the percentage values were respectively 65 and 62. In the south-west of England sunless

days were rather more frequent than in April, but in our eastern and southern counties and in the Channel Islands there were no such occasions. Three out of the six Irish stations also reported an entire absence of sunless days,—a somewhat remarkable fact when we remember that the total duration for the month was considerably less than the normal.

June was far more sunny than May, the only stations showing a deficiency being Aberdeen and Parsonstown. In the eastern and midland counties of England the difference from the average was not very large, but in the southern counties the excess was greater, while in the south-western districts and the Channel Islands it was very considerable. The percentage of the possible duration was again below 40 at several of the northern English stations, and below 50 in the eastern and midland counties. In the southern districts, however, it exceeded 50, and on the coasts of Devon and Cornwall it exceeded 60, while at Jersey the sunshine again amounted, as in April, to 72 per cent. of the possible. The mean amount of sunshine per day was as much as 10·5 hours at Falmouth and 11·0 hours at Newquay and Guernsey, while at Jersey it was no less than 11·5 hours, the total amount registered during the month at the last mentioned station being the largest ever observed in any part of the Kingdom.

The record for the entire four months is given in the last five columns of the table and also in a more graphic form in the map, Fig. 8 (p. 14), which shows the relative prevalence of sunshine over different parts of the country. The figures on the map give for certain selected stations, firstly, in italic type, the number of sunless days, and secondly, in ordinary type, the mean daily amount recorded during the whole four months.

The stations in Ireland and Scotland are not sufficiently numerous to enable any very correct conclusions to be drawn, but so far as the records go they show that the percentage of the possible duration was below 40 in most parts of those countries, the lowest value of all being 22 per cent. at Fort Augustus. Over the northern parts of England, and also in the south and east of Ireland, there was, generally speaking, between 40 and 50 per cent. of the possible amount, but at Manchester, where the effects of smoke probably came into operation, the percentage value was as low as 88. In nearly all the more southern parts of England and Wales the percentage was above 50, the only exceptions being Greenwich and Margate; at the former station there was only 44 per cent., and at the latter 48 per cent. On the south and south-west coasts of England the values ranged between 55 and 60, the latter figure being reached at Falmouth. This very high percentage was, however, considerably exceeded in the Channel Islands, the value both at Guernsey and Jersey being no less than 67 per cent.

To grasp the full significance of these facts it must be borne in mind that if the sun shines during a whole month for more than half the possible time the record is considered a remarkably good one, a percentage of 60 or more for such a period being very unusual in these Islands. During the period under discussion we have at a large number of stations on our south and south-west coasts a percentage very little under 60 for a period extending

TABLE III.—DURATION OF BRIGHT SUNSHINE IN VARIOUS PARTS OF THE UNITED KINGDOM, MARCH TO JUNE 1893.

Stations.	March.					April.					May.					June.					The Entire Period.				
	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.
SCOTLAND, N.	hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.	
Stornoway	92	— 7	25	3·0	3	163	+ 11	38	5·4	1	138	—48	27	4·5	3	180	+ 1	34	6·0	4	573	— 43	31	4·7	11
Fort Augustus	63	?	17	2·0	13	124	?	29	4·1	7	85	?	17	2·7	9	135	?	26	4·5	7	407	?	22	3·3	36
Fort William	107	?	30	3·5	6	174	?	41	5·8	3	128	?	25	4·1	2	174	?	33	5·8	5	583	?	32	4·8	16
SCOTLAND, E.																									
Aberdeen	179	+67	49	5·8	4	164	+ 21	39	5·5	4	153	—40	30	4·9	6	173	—22	33	5·8	5	669	+ 26	37	5·5	19
*Braemar	168	?	46	5·4	2	173	?	41	5·8	6	160	?	32	5·2	4	186	?	35	6·2	7	687	?	38	5·6	19
Edinburgh	137	?	38	4·4	4	165	?	39	5·5	5	138	?	28	4·5	3	185	?	36	6·2	5	625	?	35	5·1	17
Marchmont	160	?	44	5·2	3	188	?	45	6·3	4	160	?	32	5·2	2	222	?	43	7·4	4	730	?	41	6·0	13
ENGLAND, N.E.																									
Durham	166	+62	46	5·4	3	173	+ 60	41	5·8	7	160	—17	32	5·2	5	194	+32	38	6·5	3	693	+137	39	5·7	18
Oswaldkirk	180	?	49	5·8	3	227	?	54	7·6	1	175	?	36	5·6	5	170	?	34	5·7	1	752	?	42	6·2	10
York	153	+54	42	4·9	4	240	+111	57	8·0	2	198	+11	40	6·4	4	197	+28	39	6·6	1	788	+204	44	6·5	11
ENGLAND, E.																									
Hillington	169	+62	46	5·5	3	244	+ 98	59	8·1	1	221	+10	46	7·1	0	230	+37	46	7·7	2	864	+207	49	7·1	6
Geldeston	193	+69	53	6·2	2	234	+ 71	57	7·8	1	236	+ 7	49	7·6	0	244	+32	50	8·1	0	907	+179	52	7·4	3
Cambridge	208	+90	57	6·7	2	266	+118	64	8·9	1	221	+21	46	7·1	0	238	+46	48	7·9	1	933	+275	53	7·6	4
Rothamsted	199	?	55	6·4	1	271	?	66	9·0	1	217	?	45	7·0	0	225	?	46	7·5	1	912	?	52	7·5	3
MIDLAND COUNTIES.																									
Worksop	164	+66	45	5·3	2	218	+ 95	52	7·3	2	182	+ 7	37	5·9	2	178	+21	36	5·9	2	742	+189	42	6·1	8
Thurcaston	183	+96	50	5·9	2	257	+142	62	8·6	1	209	+33	43	7·0	1	208	+49	42	6·9	1	857	+320	49	7·0	5
Churchstoke	198	+93	54	6·4	1	221	+ 85	53	7·4	2	208	+22	43	6·7	2	227	+49	46	7·6	0	854	+249	48	7·0	5
Cirencester	182	+72	50	5·9	1	258	+116	63	8·6	2	226	+29	47	7·3	1	214	+27	43	7·1	0	880	+244	50	7·2	4
Oxford	201	+89	55	6·5	1	256	+115	62	8·5	2	213	+21	44	6·9	1	217	+30	44	7·2	0	887	+255	51	7·3	4
ENGLAND, S.																									
Greenwich	155	+63	42	5·0	3	231	+103	56	7·7	1	187	+ 1	39	6·0	1	198	+27	40	6·6	2	771	+194	44	6·3	7
Margate	196	?	54	6·3	2	209	?	51	7·0	3	225	?	47	7·3	0	209	?	43	7·0	0	839	?	48	6·9	5
Hastings (St. Leonard's)	208	+72	57	6·7	4	282	+115	69	9·4	0	241	+ 4	50	7·8	0	281	+62	57	9·4	1	1012	+253	58	8·3	5
Eastbourne	213	?	58	6·9	4	274	?	67	9·1	0	218	?	46	7·0	0	263	?	54	8·8	1	968	?	56	7·9	5
Brighton	194	?	53	6·3	3	281	?	68	9·4	0	223	?	47	7·2	0	248	?	51	8·3	1	946	?	54	7·8	4

* At stations marked with an asterisk the values are obtained by Jordan's Photographic Recorder; in all other places Stoke's instrument, or one of a

TABLE III.—Duration of Bright Sunshine in various parts of the United Kingdom, March to June 1893—*Continued.*

Stations.	March.					April.					May.					June.					The Entire Period.				
	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.	Total No. of Hours Recorded.	Diff. from Average.	Percentage of Possible Duration.	Mean Daily Amount.	No. of Sunless Days.
England, S. – *Continued.*	hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.		hrs.	hrs.	%	hrs.	
*Westbourne	224	?	61	7·2	3	302	?	74	10·1	0	248	?	52	8·0	0	245	?	50	8·2	2	1019	?	59	8·4	5
Southampton	209	+83	57	6·7	1	277	+114	67	9·2	0	256	+45	54	8·3	0	229	+ 25	47	7·6	1	971	+267	56	8·0	2
Scotland, W.																									
Glasgow	103	+22	28	3·3	5	180	+ 53	43	6·0	4	139	−21	28	4·5	4	215	+ 56	42	7·2	3	637	+110	35	5·2	16
Douglas (Isle of Man)	175	+55	48	5·6	2	245	+ 67	59	8·2	4	189	−35	39	6·1	3	263	+ 46	52	8·8	1	872	+133	49	7·1	10
England, N.W.																									
Newton Reigny	171	+71	47	5·5	2	236	+ 95	56	7·9	2	170	−32	34	5·5	1	233	+ 41	46	7·8	0	810	+175	45	6·6	5
Stonyhurst	162	+64	45	5·2	8	224	+ 88	54	7·5	2	177	−16	36	5·7	3	207	+ 22	41	6·9	1	770	+158	43	6·3	14
Blackpool	146	+52	40	4·7	?	214	+ 70	51	7·1	3	170	−31	35	5·5	3	228	+ 39	45	7·6	0	758	+130	43	6·2	?
*Manchester	135	?	37	4·4	4	194	?	47	6·5	2	161	?	33	5·2	3	189	?	38	6·3	1	679	?	38	5·6	10
Llandudno	155	+64	43	5·0	3	207	+ 69	50	6·9	1	182	−10	37	5·9	4	264	+ 85	53	8·8	1	808	+208	46	6·6	9
England, S.W.																									
Pembroke	174	+44	48	5·6	2	250	+ 67	61	8·3	1	224	+ 9	47	7·2	1	272	+ 38	55	9·1	0	920	+158	53	7·5	4
*Tenby	187	?	51	6·0	4	268	?	65	8·9	1	242	?	50	7·8	1	271	?	55	9·0	0	968	?	55	7·9	6
Cullompton	195	+76	53	6·3	3	268	+123	65	8·9	0	213	+20	45	6·9	1	275	+ 81	56	9·2	0	951	+300	55	7·8	4
*Torquay	210	?	58	6·8	2	279	?	68	9·3	0	229	?	48	7·4	0	294	?	61	9·8	0	1012	?	58	8·3	2
Newquay	192	?	53	6·2	3	261	?	64	8·7	0	228	?	48	7·4	3	331	?	68	11·0	0	1012	?	58	8·3	6
Falmouth	209	+79	57	6·7	3	270	+ 97	66	9·0	0	254	+38	54	8·2	2	314	+ 89	65	10·5	1	1047	+303	60	8·6	6
Plymouth	208	+77	57	6·7	4	276	+107	67	9·2	0	233	+26	49	7·5	0	308	+105	64	10·3	0	1025	+315	59	8·4	4
Ireland, N.																									
Markree Castle	88	−13	24	2·8	7	164	+ 14	39	5·5	5	126	−61	26	4·1	1	215	+ 57	43	7·2	0	593	− 3	33	4·9	13
Armagh	121	+28	33	3·9	5	182	+ 43	44	6·1	3	126	−59	26	4·1	1	191	+ 20	38	6·4	1	620	+ 32	35	5·1	10
Arley Cottage	117	?	32	3·8	6	173	?	41	5·8	3	127	?	26	4·1	0	180	?	36	6·0	1	597	?	34	4·9	10
Ireland, S.																									
Dublin	158	+43	43	5·1	2	236	+ 74	57	7·9	1	175	−38	36	5·6	0	218	+ 33	44	7·3	0	787	+112	45	6·5	3
Parsonstown	123	+ 9	34	4·0	9	190	+ 30	46	6·3	2	127	−61	26	4·1	0	159	− 16	32	5·3	4	599	− 38	34	4·9	15
Valencia	113	−20	31	3·6	9	209	+ 39	51	7·0	2	182	−28	38	5·9	2	227	+ 29	46	7·6	3	731	+ 20	42	6·0	16
Channel Islands.																									
*Guernsey	228	?	63	7·4	2	289	?	71	9·6	0	303	?	65	9·8	0	331		69	11·0	0	1151	?	67	9·4	2
Jersey	222	+73	61	7·2	3	296	+108	72	9·9	0	291	+48	62	9·4	0	344	+110	72	11·5	0	1153	+339	67	9·5	3

* At stations marked with an asterisk, the values are obtained by Jordan's Photographic Recorder; in all other places Stokes' instrument, or one of a similar construction, is employed.

over four months, while in the Channel Islands the sun actually shone during this lengthy interval for more than two-thirds of the time it was above the horizon. A careful examination of the records since the year 1881 shows no such spell of fine weather, the only approach to it being in the splendid summer of 1887, when the percentage at Jersey for the three months June, July, and August was over 60. The value, however, for that period was

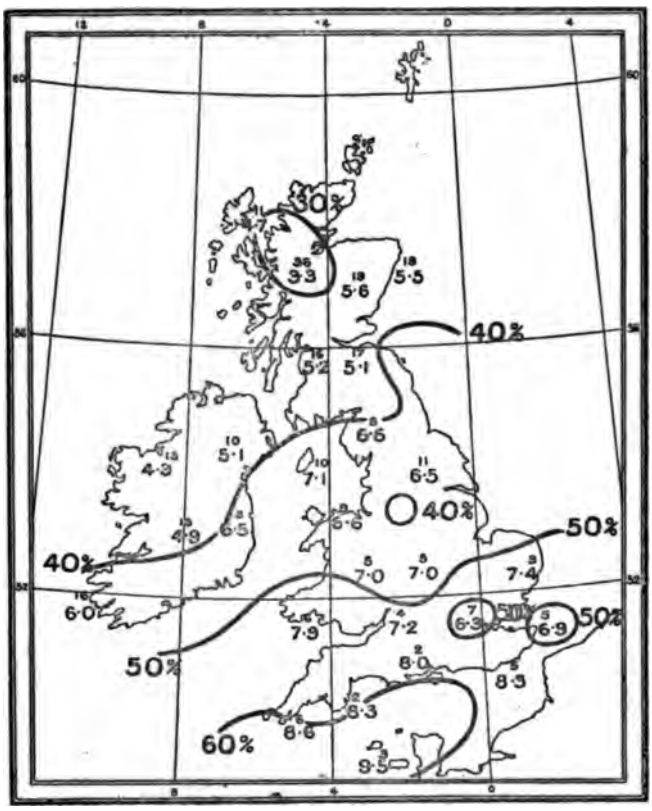


FIG. 3.
Percentage of Bright Sunshine, March to June 1893.

NOTE.—The percentage of possible sunshine is shown by the thick lines. The small figures represent the number of sunless days, and the ordinary figures give the mean daily proportion of bright sunshine.

lower than it was this year, and if, to make the comparison complete, we add either May or September, as a fourth month, to the 1887 record, we get a very much smaller percentage than that given in the period under discussion. As regards the daily proportion of sunshine, it appears that during the four months there was more than 7 hours per day in the midland counties, about 7½ hours in England East, and between 8 and 8½ hours on our south and south-west coasts, while in the Channel Islands the daily proportion for the entire period was no less than 9½ hours. The smallest number of sunless

days in the four months was 2 at Southampton, Torquay and Guernsey, and 8 at Rothamsted, Dublin and Jersey, but many other stations over the southern parts of the Kingdom reported only 4 or 5 such occasions. In the Channel Islands, and also at Torquay and Plymouth, there was not one sunless day during the whole of April, May, and June.

Rainfall and the Drought.

The principal facts relating to the rainfall of the period are given in Table IV., which has been compiled from the returns furnished by 78 stations situated in various parts of the United Kingdom and published in the *Weekly Weather Report*. At the commencement of the inquiry the author was tempted to avail himself of observations made at a number of additional places, but on further reflection it appeared that while the inclusion of these would probably have led to the discovery of interesting local peculiarities, the additional labour involved in the search would have resulted for the most part in a simple accumulation of facts. The stations employed are fairly well distributed over the Kingdom, and the general survey they give of the actual state of affairs seems to be sufficiently complete for all practical purposes. The table shows for each month and for the entire period,—firstly, the number of rainy days experienced at each station; secondly, the total fall; and thirdly, the proportion of the average amount expressed in the form of percentages. The averages employed are mainly those for the 25 years 1866-90. Statistics relating to the drought are also included in the table. An explanation of the method on which these figures are drawn up will follow when we come to deal with the drought itself. For the present it will be sufficient to consider the question of the rain.

Rainfall.

In the course of our remarks on the distribution of barometric pressure attention was more than once drawn to the singularly local character of many of the rains experienced, some localities being favoured with fairly large amounts, while neighbouring places escaped with but a slight sprinkling or perhaps with no rain at all. This peculiar feature in the weather of the period comes out very clearly in the monthly values given in Table IV. A careful examination shows that in nearly every month, and in nearly every district, the rainfall at one of the stations in the district amounted to twice or more than twice that recorded at some other station in the same district, while in many instances the discrepancy was even more striking. Owing to these local variations our remarks on the rainfall of each month are necessarily of a somewhat general character.

In March the rainfall was below the average at all but one of the 78 stations. The single exception was Glencarron, a station situated in one of the wettest parts of Scotland, and here, owing to one or two heavy falls which took place during the early part of the month, the aggregate amount was nearly half as much again as the average. Most of the other stations in the same district (Scotland N.) had three quarters or more of the normal

TABLE IV.—AMOUNT OF RAINFALL EXPERIENCED OVER THE BRITISH ISLANDS DURING THE MONTHS OF MARCH, APRIL, MAY, AND JUNE, 1893, WITH THE PROPORTION OF THE AVERAGE AMOUNT, AND STATISTICS RELATING TO THE LONG DROUGHT.

Stations.	March.			April.			May.			June.			The Entire Period.			Duration of Drought.						
																Absolute Drought.			Partial Drought.			
	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	Began.	Ended.	Duration in Days.	Began.	Ended.	Duration in Days.	Total Rainfall in Period.
SCOTLAND, N.		Ins.	%		Ins.	%		Ins.	%		Ins.	%		Ins.	%							Ins.
Sumburgh Head	23	2·51	90	17	1·20	58	16	1·46	85	10	0·60	30	66	5·77	67	..	..	..	May 28	June 26	30	0·21
Stornoway	17	1·84	49	19	1·12	42	19	1·51	58	14	1·24	44	69	5·71	48	..	..	..	..	..	..	..
Wick	17	1·32	65	12	0·96	57	11	1·39	82	12	1·09	63	52	4·76	67	..	..	..	Mar. 18	April 17	31	0·23
Lairg	19	2·32	78	15	1·86	82	18	1·49	69	12	1·10	46	64	6·77	69	..	..	..	..	..	..	..
Glencarron	20	9·14	146	18	3·51	82	18	3·84	83	19	2·24	43	75	18·73	92	..	..	..	..	..	..	..
Fort Augustus	19	2·23	75	14	1·61	79	12	1·23	59	13	1·26	57	58	6·33	68	..	..	..	..	..	..	..
Fort William	20	4·44	73	14	3·12	88	15	2·73	75	12	1·89	47	61	12·18	70	..	..	..	..	..	..	..
SCOTLAND, E.																						
Nairn	13	0·81	48	12	1·19	94	13	1·03	64	11	1·91	112	49	4·94	79	..	..	..	..	..	..	..
Aberdeen	10	0·68	29	14	0·81	38	16	1·32	66	12	3·52	199	52	6·33	77	Mar. 18	April 1	15	Mar. 9	April 16	39	0·39
Braemar	9	0·57	23	10	1·26	53	12	1·07	47	11	2·73	114	42	5·63	59	..	..	..	Mar. 11	April 14	35	0·31
Ochtertyre	10	0·91	33	6	0·96	41	11	1·23	50	7	3·15	116	34	6·25	61	Mar. 31 June 7	April 14 June 21	15 15	Mar. 16	April 14	30	0·07
Leith	8	0·60	43	9	1·15	73	11	1·55	93	8	1·76	98	36	5·06	78	June 7	June 21	15	Mar. 2 April 18	April 14 May 16	44 29	0·27 0·26
Marchmont	9	0·95	39	12	1·28	53	13	1·76	75	10	3·08	123	44	7·07	73	..	..	..	Mar. 4	April 14	42	0·40
ENGLAND, N.E.																						
Alnwick Castle	8	0·70	30	9	0·54	24	15	1·19	55	11	1·41	76	43	3·84	44	..	..	..	Mar. 2	April 15	45	0·36
Durham	9	0·43	20	8	0·37	17	12	2·33	114	11	0·81	43	40	3·94	48	..	..	..	Mar. 2	May 1	61	0·61
Shields	7	0·84	48	7	0·33	18	11	1·31	78	9	1·04	61	34	3·52	51	Mar. 27	April 14	19	Mar. 2 May 23	May 15 June 21	75 30	0·69 0·28
Scarborough	5	0·18	10	6	0·61	31	12	1·44	74	12	1·65	86	35	3·88	50	Mar. 17	April 14	29	Mar. 4	April 28	56	0·54
York	7	0·32	18	7	0·48	27	11	1·91	103	9	1·25	58	34	3·96	53	..	..	..	Mar. 1	April 15	46	0·43
Spurn Head	7	0·29	24	3	0·18	12	10	1·19	76	8	1·13	73	28	2·79	48	..	..	..	Feb. 27	May 16	79	0·75

TABLE IV.—Amount of Rainfall experienced over the British Islands during the Months of March, April, May, and June, 1893, with the Proportion of the Average Amount, and Statistics relating to the Long Drought—*Continued.*

Stations.	March.			April.			May.			June.			The Entire Period.			Duration of Drought.						
																Absolute Drought.			Partial Drought.			
	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	Began.	Ended.	Duration in Days.	Began.	Ended.	Duration in Days.	Total Rainfall in Period.
England, E.		Ins.	%		Ins.	%		Ins.	%		Ins.	%		Ins.	%							Ins.
Hillington	5	0·27	16	3	0·11	6	7	0·65	35	8	1·56	72	23	2·59	35	Mar. 17	April 15	30	Mar. 4	June 3	92	0·87
Yarmouth	9	0·44	24	5	0·13	8	8	0·80	43	11	1·10	59	33	2·47	34	May 2	May 16	15	Feb. 28	May 20	82	0·75
Geldeston	6	0·27	17	3	0·11	7	8	1·28	75	10	1·17	72	27	2·83	44	Mar. 19	April 11	24	Feb. 28	May 20	82	0·61
Cambridge	6	0·34	24	3	0·13	8	8	0·89	47	9	1·06	48	26	2·42	34	Mar. 18	April 15	29	Mar. 2	May 27	87	0·84
Rothamsted	7	0·35	20	3	0·22	10	8	1·20	55	8	0·97	43	26	2·74	33	Mar. 23 April 30	April 15 May 14	24 15	Mar. 1	May 16	77	0·68
Midland Counties.																						
Bawtry (Hesley Hall)	6	0·33	19	4	0·30	18	10	1·92	93	7	1·24	55	27	3·79	49	June 5	June 20	16	Mar. 2	May 16	76	0·63
Loughborough	7	0·30	18	4	0·34	19	9	2·40	115	7	0·89	40	27	3·93	51	Mar. 18 June 5	April 15 June 21	29 17	Mar. 1 May 21	May 16 June 21	77 32	0·77 0·22
Stamford (Ketton Hall)	7	0·24	17	4	0·43	22	10	0·76	31	9	1·00	52	30	2·43	31	Mar. 18	April 15	29	Mar. 1	May 16	77	0·76
Cheadle	11	0·78	34	4	0·53	25	10	2·28	96	8	1·40	48	33	4·99	51	..	..	..	Mar. 7	April 15	40	0·33
Churchstoke	8	0·51	25	5	0·19	10	12	2·34	108	11	1·14	53	36	4·18	51	..	..	..	Mar. 3	May 14	73	0·68
																			May 24	June 21	29	0·19
Hereford	5	0·27	16	4	0·17	9	8	2·20	105	10	1·07	50	27	3·71	48	Mar. 17	Mar. 31	15	Feb. 26	May 14	78	0·70
Cirencester	7	0·25	12	2	0·07	3	7	1·48	67	13	1·05	45	29	2·85	32	April 2	April 16	15	Feb. 26	May 14	78	0·72
Oxford	5	0·18	11	3	0·06	3	7	0·84	43	11	0·77	35	26	1·85	25	Mar. 17	April 15	30	Feb. 27	May 16	79	0·67
England, S.																						
London	8	0·39	26	4	0·10	5	8	0·47	25	9	0·87	41	29	1·83	25	Mar. 17 June 7	April 15 June 21	30 15	Feb. 28	June 21	114	1·09
North Foreland	6	0·36	?	0	..	0	7	1·12	?	5	0·52	?	18	2·00	?	Mar. 22	May 14	54	Feb. 28 May 22	May 20 June 22	82 32	0·82 0·32
Strathfield Turgiss	9	0·37	24	2	0·12	7	10	1·01	56	14	0·80	40	35	2·30	32	Mar. 17	April 15	30	Mar. 1 May 24	May 16 June 21	77 29	0·67 0·28

TABLE IV.—Amount of Rainfall experienced over the British Islands during the Months of March, April, May, and June, 1893, with the Proportion of the Average Amount, and Statistics relating to the Long Drought—*Continued.*

Stations.	March.			April.			May.			June.			The Entire Period.			Duration of Drought.						
																Absolute Drought.			Partial Drought.			
	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	Began.	Ended.	Duration in Days.	Began.	Ended.	Duration in Days.	Total Rainfall in Period.
England, S.—*Continued.*		Ins.	%		Ins.	%		Ins.	%		Ins.	%		Ins.	%							Ins.
Dungeness	6	0·23	13	1	0·01	1	6	0·39	22	10	0·37	23	23	1·00	14	Mar. 18	April 15	29*	Feb. 27	July 3	127	1·27
																April 17	May 15	29				
Hastings (St. Leonard's)	6	0·38	20	1	0·02	1	7	0·63	35	9	0·91	55	23	1·94	26	Mar. 18	April 15	29†	Mar. 2	June 4	95	0·93
																April 17	May 14	28				
Southampton	5	0·26	13	2	0·07	3	6	0·84	41	8	1·03	54	21	2·20	27	Mar. 17	April 15	30	Feb. 28	May 16	78	0·73
																April 30	May 14	15	May 21	June 21	32	0·31
																May 21	June 4	15				
Hurst Castle	7	0·66	36	0	..	0	6	0·80	45	7	0·84	44	20	2·30	31	Mar. 18	May 15	59	Feb. 28	May 16	78	0·72
																June 6	June 21	16	May 21	June 25	36	0·28
Stowell	10	0·69	?	4	0·14	?	11	1·15	?	15	1·63	?	40	3·61	?	Mar. 17	April 15	30	Mar. 3	May 16	75	0·75
Scotland, W.																						
Laudale (Loch Sunart)	21	3·47	53	13	1·85	46	20	2·81	71	9	0·60	12	63	8·73	45	..	..	..	..	..	..	..
Glasgow	9	1·40	56	8	1·37	63	14	3·07	128	7	1·56	58	38	7·40	76	June 7	June 21	15	Mar. 17	April 14	29	0·20
Ardrossan	14	1·34	55	8	1·87	87	14	1·99	85	8	1·26	51	44	6·46	69	June 7	June 21	15	Mar. 17	April 14	29	0·27
Glenlee	13	2·71	69	9	1·39	48	13	2·82	95	10	2·03	63	45	8·95	69	..	..	..	Mar. 17	April 15	30	0·22
Douglas (Isle of Man)	11	1·05	37	6	1·28	55	13	1·43	66	8	1·45	67	38	5·21	55	April 1	April 15	15	Mar. 4	April 15	43	0·31
																			May 23	June 22	31	0·25
England, N.W.																						
Newton Reigny	8	1·67	75	5	0·41	22	10	1·57	77	9	2·08	100	32	5·73	70	..	..	..	Mar. 17	May 16	61	0·53
Stonyhurst	14	1·70	49	8	0·81	34	12	2·45	93	11	2·40	74	45	7·36	63	June 7	June 21	15	Mar. 17	April 15	30	0·27
Blackpool	8	0·79	35	4	0·37	22	10	1·74	85	7	1·27	60	29	4·17	51	Mar. 18	April 15	29	Mar. 7	May 14	69	0·68
																June 4	June 21	18	May 21	June 21	32	0·21
Manchester	11	0·70	28	6	0·79	40	11	2·11	88	11	1·92	64	39	5·52	56	..	..	..	Mar. 17	April 15	30	0·27

* Drought interrupted by a fall of 0·01 inch on April 16.
† Do. Do. Do. 0·02 Do. Do.

TABLE IV.—Amount of Rainfall experienced over the British Islands during the Months of March, April, May, and June, 1893, with the Proportion of the Average Amount, and Statistics relating to the Long Drought—*Continued.*

Stations.	March.			April.			May.			June.			The Entire Period.			Duration of Drought.						
																Absolute Drought.			Partial Drought.			
	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	Began.	Ended.	Duration in Days.	Began.	Ended.	Duration in Days.	Total Rainfall in Period.
England, N.W.—*Continued.*		Ins.	%		Ins.	%		Ins.	%		Ins.	%		Ins.	%							Ins.
Liverpool Obs. (Bidston)	9	0·55	32	4	0·50	32	14	1·62	88	8	1·54	81	35	4·21	60	..	..	..	Mar. 3	April 15	44	0·33
Llandudno	7	0·77	39	5	0·87	48	11	1·75	97	7	2·14	118	30	5·53	74	April 1	April 15	15	Mar. 4	April 15	43	0·30
Holyhead	8	0·73	32	6	0·86	45	10	1·24	65	12	1·25	63	36	4·08	51	April 1	April 15	15	Mar. 4	April 15	43	0·27
England, S.W.																						
Llandovery	10	0·80	22	3	0·11	4	12	2·32	82	12	2·43	82	37	5·66	46	..	..	..	Mar. 4	April 30	58	0·43
Pembroke	11	0·47	20	5	0·32	16	10	0·76	37	7	0·65	34	33	2·20	26	June 7	June 23	17	Mar. 7	May 15	70	0·68
																			May 21	June 25	36	0·17
Arlington (N. Devon)	9	0·92	26	3	0·20	7	11	2·10	71	7	1·43	44	30	4·65	37	April 2	April 21	20				
																May 24	June 12	20	Mar. 16	May 14	60	0·58
Cullompton	7	0·44	18	3	0·17	7	11	2·31	106	8	0·93	40	29	3·85	40	April 2	April 21	20	Mar. 1	May 14	75	0·72
																			May 21	June 21	32	0·29
																Mar. 17	Mar. 31	15				
Falmouth	7	0·54	16	2	0·06	2	7	0·67	24	8	1·21	47	24	2·48	21	April 6	April 28	23	Mar. 2	June 22	113	1·06
																May 23	June 11	20				
Plymouth	8	0·26	10	3	0·65	27	9	1·65	80	7	0·84	42	27	3·40	37	May 31	June 21	22	Mar. 1	April 21	52	0·34
																			May 20	June 25	37	0·37
																April 2	April 21	20				
Prawle Point	7	0·18	9	3	0·79	38	7	0·80	51	6	0·73	46	23	2·50	35	April 30	May 15	16	Feb. 27	April 21	54	0·51
																May 24	June 12	20	May 19	June 24	37	0·36
Ireland, N.																						
Malin Head	16	1·33	?	7	1·16	?	13	1·22	?	11	1·40	?	47	5·11	?	..	..	..	Mar. 17	April 14	29	0·27
Londonderry.....	17	2·14	77	8	1·21	53	15	1·35	57	11	2·06	81	51	6·76	68	..	..	..	..	..	..	..
Edenfel (Omagh)	17	1·71	72	7	1·59	75	11	1·30	56	14	1·87	72	49	6·47	69	April 1	April 15	15	..	..	..	..
Belmullet	16	1·80	?	14	1·80	?	15	2·22	?	15	2·07	?	60	7·89	?	..	..	..	Mar. 18	April 15	29	0·25
Markree Castle.....	16	1·55	62	12	1·58	64	15	1·53	75	12	2·54	84	55	7·20	72	..	..	..	..	..	..	..

TABLE IV.—Amount of Rainfall experienced over the British Islands during the Months of March, April, May, and June, 1893, with the Proportion of the Average Amount, and Statistics relating to the Long Drought—*Continued.*

Stations.	March.			April.			May.			June.			The Entire Period.			Duration of Drought.						
																Absolute Drought.			Partial Drought.			
	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	No. of Rainy Days.	Total Rainfall.	Percentage of Average Amount.	Began.	Ended.	Duration in Days.	Began.	Ended.	Duration in Days.	Total Rainfall in Period.
		Ins.	%		Ins.	%		Ins.	%		Ins.	%		Ins.	%							Ins.
Ireland, N.—*Continued.*																						
Brookeborough	14	1·43	51	7	0·97	38	13	1·63	65	13	2·83	98	47	6·86	64	..	..	..	..	..	..	..
Armagh	11	1·00	48	11	0·94	44	13	1·12	55	9	1·59	75	44	4·65	55	June 7	June 22	16	Mar. 17	April 15	30	0·22
Donaghadee	13	0·74	36	7	1·16	60	11	0·99	44	12	1·65	86	43	4·54	56	..	..	..	Mar. 17	April 15	30	0·23
																			May 24	June 21	29	0·28
Edgeworthstown	14	1·01	36	6	1·00	43	11	2·47	101	12	2·68	89	43	7·16	68	April 1	April 15	15	Mar. 17	April 15	30	0·30
Ireland, S.																						
Dublin	8	0·29	14	7	1·05	52	10	1·67	84	12	1·72	93	37	4·73	59	April 1	April 15	15	Feb. 26	April 15	49	0·42
Parsonstown	10	0·61	26	7	0·76	37	11	2·82	126	8	2·54	106	36	6·73	75	..	..	..	Mar. 16	April 15	31	0·29
Kilkenny	10	0·38	18	7	0·69	32	12	2·31	116	9	1·83	83	38	5·21	61	June 7	June 21	15	Mar. 1	April 15	46	0·41
Waterford	7	0·56	18	4	0·62	24	11	1·59	67	8	1·66	69	30	4·43	42	April 1	April 15	15	Mar. 4	April 15	43	0·34
																June 7	June 21	15				
																Mar. 16	Mar. 30	15*				
Roche's Point	5	0·12	3	5	1·57	49	11	2·54	81	6	1·87	60	27	6·10	46	April 1	April 15	15	Mar. 1	April 16	47	0·24
																June 7	June 24	18				
Valencia	17	1·23	29	9	1·09	28	11	1·79	56	13	2·07	63	50	6·18	43	..	..	..	..	..	..	..
Killarney	9	0·68	?	11	1·28	?	9	0·98	?	12	1·53	?	41	4·47	?	..	..	..	..	..	..	..
Foynes	9	0·44	?	8	1·34	?	8	1·26	?	12	1·51	?	37	4·55	?	..	..	..	..	..	..	..
Channel Islands.																						
Scilly (St. Mary's)	7	0·34	14	2	0·18	8	7	0·61	35	5	0·63	34	21	1·76	21	April 2	April 20	19	Mar. 1	May 17	78	0·60
																June 4	June 22	19	May 20	June 24	36	0·33
Jersey	12	0·61	26	2	0·34	16	9	1·79	96	5	0·58	30	28	3·32	41	Mar. 19	April 10	23	Mar. 7	May 15	70	0·69
																April 23	May 13	21	May 21	June 25	36	0·34
																May 24	June 12	20				

* Drought interrupted by a fall of 0·01 inch on March 31.

quantity, but at Stornoway the total fall was only 49 per cent. of the average. In the west of Scotland and the north of Ireland the rainfall, though less abundant than it was further north, amounted to more than half the average, the largest percentage values in these districts being 77 at Londonderry, 72 at Edenfel (Omagh), and 69 at Glenlee. At Newton Reigny also, situated on the borders of England N.W., the fall amounted to 75 per cent. of the average. With the exception of these extreme north-western and northern stations the rainfall in March amounted in all cases to less than half the average, while over a considerable portion of England as well as in the south of Ireland it was less than one quarter of the normal amount. The driest station of all was Roche's Point, where the total rainfall (0·12 in.) amounted to only 8 per cent. of the average. Next to this came Prawle Point with 9 per cent., Plymouth and Scarborough with 10 per cent., and Oxford with 11 per cent. Over a considerable portion of our eastern, central, and southern counties there was no rain at all after the middle of the month.

In April the absence of rain was upon the whole far more striking than in March, a deficiency being reported in all parts of the Kingdom. At the extreme northern and north-western stations the deficiency was somewhat small, over 60 per cent. of the average being reported at several of the stations in Ireland N., and over 80 per cent. at three out of the seven stations in Scotland N. and at one station in Scotland W. At Nairn (in Scotland E.) there was as much as 94 per cent. of the normal quantity. At many of the stations situated in the north-west of England and the south of Ireland the rainfall of April exceeded that of March, but over England generally the weather was very much drier. Over our eastern, southern, and south-western counties, and also in the more southern parts of the midland district, the total fall amounted to less than one tenth of the average, while in many places the proportion was very much smaller. The driest region of all was undoubtedly the extreme south; at Hastings the month's rainfall amounted to only 0·02 in., and at Dungeness to 0·01 in., while at the North Foreland and Hurst Castle there was no rain at all.

In May the weather was far less dry than in either March or April, an actual excess of rain being reported at several stations over central and northern England, as well as at Glasgow and in many of the central Irish districts. In the east and south of England there was again a large deficiency, less than half the average being reported at the majority of stations. The driest localities of all were Dungeness with 22 per cent. of the normal amount, Falmouth with 24 per cent., and London with 25 per cent.

In June the deficiency of rain was more general than in May, the only district in which the values were above the average being the east of Scotland; at Aberdeen the amount was nearly double the normal. At the majority of stations situated in the central and southern parts of England, and also in the west and north of Scotland, the amounts were less than half the normal, the smallest proportion of all (12 per cent.) being reported, singularly enough, at Laudale on Loch Sunart, a district famous for heavy rains. Over England

the smallest percentage values were 28 at Dungeness, 80 at Jersey, and 84 at Pembroke and Scilly.

Taking the period of four months as a whole, the figures show, as one would naturally expect, that there was a deficiency of rain in all parts of the Kingdom, the only station at which the fall approximated to the average being Glencarron, where the percentage reached 92. In the east and south of Scotland the fall amounted to more than three-fourths of the average, and in the west of Ireland it was not very much short of the same proportion. The districts in which the rainfall failed to reach one half of the average amount comprised all the more southern and eastern parts of England, with the extreme south of Ireland and a portion of Durham and Northumberland. A similar deficiency was also reported in the west of Scotland, at the two stations Stornoway and Laudale. Over the southern counties of England generally the fall amounted to less than one third of the average, the only stations at which this proportion was exceeded being those in more central parts of Devonshire. In London and at Oxford there was exactly one quarter of the average quantity, while at Pembroke there was very little more than one quarter. The driest localities of all were, however, those situated in the extreme south-east and south-west of England. At Scilly and Falmouth the total fall amounted to only 21 per cent. of the average, while at Dungeness the percentage value was as low as 14, the fall for the whole four months being less than one seventh of the usual quantity. The smallest number of days with rain was at the North Foreland, where there were only 18, next to this we find Hurst Castle with 20, Southampton and Scilly with 21, and Hillington, Dungeness, Hastings, and Prawle Point with 23.

In order to test the truth of the general impression regarding the very exceptional character of the period, the records made over a long series of years in London and at Oxford have been examined. For the Metropolis recourse has been had to the Meteorological Office records extending back to the year 1865, and prior to this to the Rainfall values for the London district published some years since by Mr. G. Dines. The latter extend back as far as the year 1813, but as they are compiled from returns kept at a number of stations in the neighbourhood of the Metropolis, they are not strictly comparable with observations made at a single station. The record is, however, generally held to be the most complete and reliable one in existence. For Oxford the records published by the Radcliffe Observatory, which extend back to the year 1851, have been used.

The London record for more than 80 years past fails to show any period of four months at any season with so small a rainfall as that of the present year. In the period under discussion the total for the four months in London was only 1·83 in., the nearest approach to it being in the months of October 1879 to January 1880, when the total was 2·17 ins.

The Oxford record, for 42 years past, also contains no such an amount as that recorded in the period under discussion. The nearest approach to it was in the months of January to April 1892, when the total was 2·50 ins.;

after which come, as in London, the four months October 1879 to January 1880, with a total of 2·54 ins. In 1893 the fall was only 1·85 in. It seems not a little singular that one of the driest periods on record should have occurred in 1879, a year which was remarkable for bad weather, and in which the rainfall for the entire twelve months was largely in excess of the average.

The Drought.

The drought statistics, given in Table IV., are drawn up on the basis of the definitions laid down by Mr. Symons in *British Rainfall* for the year 1887. These definitions are as follows:—

1. *Absolute Drought.* Periods of more than 14 consecutive days without any measureable quantity of rain.

2. *Partial Drought.* Periods of more than 28 consecutive days the aggregate rainfall of which does not exceed 0·01 in. *per diem.*

In addition to these an *Engineer's* drought was defined as a period of three or more consecutive months the aggregate rainfall of which is less than one half the average.

Table IV. clearly shows that an Engineer's drought prevailed to a greater or less extent in all the more southern parts of England, as well as at some stations situated in the south of Ireland and the west of Scotland. In many places the three months' limit might indeed be multiplied by two. In London and at Oxford, for example, the deficiency of rain was prolonged over seven months, the total fall between March and September being only slightly over 48 per cent. of the average at Oxford, and rather less than 46 per cent. in the Metropolis. At many other stations in the south of England the rainfall of July was sufficiently heavy to terminate the long drought.

Turning now to the statistics relating to the drought in its absolute and also in its partial sense, we see from the table that the only portions of the United Kingdom altogether unaffected were the western stations in Scotland N. and several of the northern and south-western stations in Ireland, or, speaking generally, the extreme western and north-western parts of the United Kingdom. At two of the stations in Ireland N., viz. Malin Head and Belmullet, there was a partial drought lasting for 29 days, while in the Shetlands and Caithness there was one lasting for 30 or 31 days. Two other stations in Ireland N. experienced an absolute drought continuing for 15 or 16 days, and a partial drought lasting over 30 days. In Scotland E., and in the more northern and eastern parts of Ireland S., the drought was fairly general, the returns from the former district showing in many cases an absolute drought extending over 15, and a partial drought lasting over 35 days; at Leith there were two partial droughts, one lasting for 44 and the other for 29 days. In the northern and eastern parts of Ireland S. there were one or two absolute periods, and at Roche's Point as many as three, the partial spells extending over periods ranging from 31 days at Parsonstown to 49 at Dublin. Most of the stations in Scotland W. experienced an absolute

drought for 15 days, and a partial drought ranging in most cases between 29 and 31 days. At Douglas, Isle of Man, however, there were two partial periods,—one of 48 and the other of 31 days. In England N.W. three stations out of the seven had an absolute drought lasting for 15 days, while at another station (Blackpool) there was one absolute period of 29 and another of 18 days. The partial drought in England N.W. varied greatly in duration in different places; at Stonyhurst and Manchester there were only 30 days, but at Newton Reigny there were as many as 61, while at Blackpool there was one period of 69, followed after a week's interval by another of 32 days. Similarly large variations were reported in the north-east of England, for while four stations out of the six escaped an absolute drought, one other station had 19 days without rain, and another station as many as 29 days. All parts of the district reported a partial drought, the number of days ranging from 45 at Alnwick Castle, and 46 at York, to 79 at Spurn Head, and to 75, followed by another 30 day period, at Shields.

Coming now to the districts more seriously affected, we find in the first place that in the midland counties six stations out of eight experienced an absolute drought, the number of days ranging from 15 at Hereford and Cirencester to 30 at Oxford. At Loughborough there was one period of 29 days between March and April, and another period of 17 days in June. The partial drought lasted in most places from 75 to 79 days, while at Loughborough and Churchstoke this very long period was supplemented by a shorter one, which continued respectively for 32 and 29 days.

In the east of England all stations were affected both in an absolute and also in a partial degree. At Yarmouth the length of the absolute drought was only 15 days, but at all other stations it exceeded 20, and at Hillington it reached 30 days. At Rothamsted there was one long period of 24 followed by a shorter one of 15 days. The partial drought in the eastern counties lasted for over 30 days at four out of the five stations, the longest spell being at Hillington, where it extended over 92 days.

In the south-western counties of England the drought, though less continuous than in the eastern districts, was upon the whole rather more severe. In place of one long period of intensely dry weather, there were in most cases two or three, each lasting for 15 or 20 days. At Falmouth there was one absolute drought of 15 days in March, followed by another of 23 in April, and by a third of 20 between May and June. The partial drought was also divided by intervals of copious rainfall, excepting at Falmouth, where it lasted continuously over a period of 118 days. In most of the cases there was one long drought lasting between 50 and 70 days in the early part of the period, followed by a shorter one of about 35 days between the months of May and June.

The district most affected was, however, undoubtedly the south of England, or rather that portion of it bounded by Dorsetshire in the west, Wiltshire, Berkshire, and Middlesex in the north, and Kent in the east. In an absolute degree the severity of the drought varied in different localities, some places being exposed to one long period of rainless weather, while others

experienced two or even three spells of a shorter duration. The longest absolute period was at Hurst Castle, where there were 59 consecutive days without rain, next to which comes the North Foreland with 54. At Dungeness and Hastings the absolute drought would have lasted as long as at Hurst Castle had it not been for some showers which fell on April 16th ; at the former station these only yielded 0·01 in., and at Hastings 0·02 in., but they were

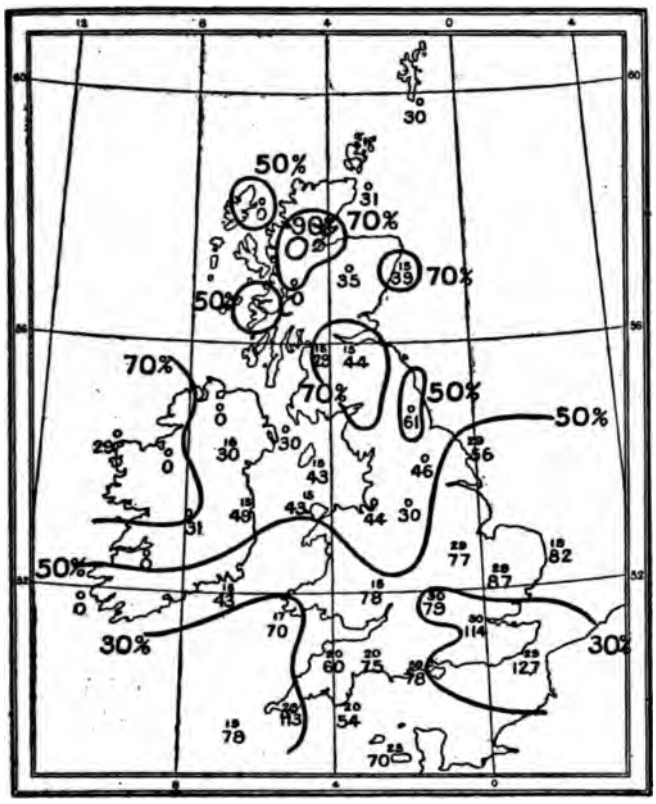


FIG. 4.
Proportion of average amount of Rainfall, March to June 1893.

NOTE.—The percentage of the average amount of Rainfall (in percentage form) is shown by the thick lines. The small figures show the duration in days of the longest *absolute* drought, and the ordinary figures give the duration of the longest *partial* drought.

quite sufficient to interrupt the rainless period, which would otherwise have lasted for 59 and 58 days respectively. In London, and also at Strathfield Turgiss, Southampton, and Stowell, the longest period of rainless weather lasted for 30 days, but in the Metropolis it was followed in June by another spell of 15 days. The period of partial drought was also interrupted in many cases by some copious rains which fell during the latter part of May. At four stations out of the eight given in the district there was one long period ranging between 77 and 82 days, followed by a shorter one ranging between 29 and 36 days.

TABLE V.—DROUGHTS EXPERIENCED IN LONDON SINCE THE YEAR 1865.

Absolute Drought.			Partial Drought.			
Began.	Ended.	Duration in Days.	Began.	Ended.	Duration in Days.	Total Rainfall in Period.
						Ins.
1865. June 3	June 28	26	.....	None ..	..	....
,, Sept. 22	Oct. 7	16	.....	.....	..	....
1866.....	None	..	.....	None ..	..	....
1867.....	None	..	Oct. 28	Nov. 29	33	0·33
1868. June 5	June 19	15	.....	None ..	..	....
,, June 24	July 10	17	.....	.....	..	....
,, Aug. 27	Sept. 15	20	.....	.....	..	....
1869. June 22	July 7	16	June 18	July 27	40	0·34
,, Aug. 17	Sept. 4	19	.....	.....	..	....
1870. Apr. 11	April 25....	15	Mar. 27	April 27	32	0·32
,, Sept. 14	Oct. 2	19	April 11	May 10	30	0·30
,, ...	.....	..	May 14	June 15	33	0·19
1871.....	None	..	Oct. 22	Dec. 18	58	0·55
1872. Aug. 10	Aug. 24	15	.....	None ..	..	....
1873.....	None	..	Nov. 30	Dec. 29	30	0·29
1874. Apr. 18	May 2	15	Jan. 25	Feb. 24	31	0·28
,, ...	.....	..	April 14	May 21	38	0·21
1875.....	None	..	Mar. 8	April 5	29	0·22
1876. May 1	May 21	21		None ..	..	....
1877. Sept. 22	Oct. 6	15	Sept. 11	Oct. 9	29	0·27
1878.....	None	..	.....	None ..	..	....
1879. Dec. 6	Dec. 26	21	Nov. 22	Dec. 29	38	0·36
1880. Jan. 17	Feb. 4	19	April 20	May 30	41	0·39
,, Mar. 8	Mar. 30	23	Aug. 8	Sept. 10	34	0·22
,, May 12	May 26	15	.....	.....	..	....
,, Aug. 9	Aug. 23	15	.....	.....	..	....
1881. Mar. 25	April 10....	17	.....	None ..	..	....
1882. Jan. 12	Jan. 28	17	Jan. 9	Feb. 13	36	0·30
,, Mar. 27	April 11	16	.....	.....	..	....
,, July 28	Aug. 11	15	.....	.....	..	....
1883. Mar. 31	April 17....	18	Mar. 20	April 17	29	0·13
,, May 27	June 14	19	July 24	Aug. 30	38	0·32
1884. June 10	June 28	19	May 6	June 3	29	0·29
,, Dec. 21	Jan. 4, 1885	15	July 28	Aug. 26	30	0·30
,, ...	.....	..	Sept. 7	Oct. 5	29	0·26
1885. July 20	Aug. 4	16	July 12	Aug. 19	39	0·31
1886. June 23	July 10	18	.....	None ..	..	....
1887. Apr. 6	April 20....	15	Feb. 3	Mar. 10	36	0·28
,, June 9	July 3	25	June 4	July 14	41	0·18
1888...	None	..	.....	None ..	..	....
1889.....	None	..	.....	None ..	..	...
1890.....	None	..	.....	None ..	..	....
1891. Feb. 7	Feb. 28....	22	Jan. 31	Mar. 6	35	0·14
1892. Mar. 28	April 12....	16	.....	None ..	..	....
,, Dec. 15	Dec. 31	17	.....	.....	..	....
1893. Mar. 17	April 15....	30	Feb. 28	June 21	114	1·09
,, June 7	June 21	15	.....	.....	..	....

At another station, Stowell in Dorsetshire, the longer period was alone experienced, while at the three remaining stations there was one very long period exceeding in duration anything experienced in other parts of the district. At Hastings the partial drought continued for 95, while in London it lasted for as many as 114 days. The longest spell of all was,

however, at Dungeness, where the number of days amounted to no fewer than 127, the period commencing with February 27th and ending with July 3rd.

The general state of affairs relating to the rainfall and drought of the entire four months is graphically shown in Fig. 4, which gives, firstly, the percentage of the average rainfall in the different parts of the Kingdom, and secondly, by figures, the duration of the drought at certain selected stations. To avoid overcrowding the map I have, in cases where two or more droughts prevailed, chosen only the longest. The information is therefore less complete than that given in the table.

In order to obtain some idea of the exceptional character of the weather of the period, a list has been prepared (Table V.) giving the duration of all the absolute and partial droughts experienced in London since the year 1865. The table is based entirely on the London observations given in the *Daily Weather Report*.

A very superficial examination of the figures is sufficient to show that, both in an absolute and also in a partial degree, the drought of 1893 was considerably longer than any other recorded in the course of the past 29 years. The nearest approach to the period of 80 rainless days experienced this year was in June 1865, when a drought extended to 26 days. Next to this came 1887 with a period in June and July extending to 25 days, and March 1880 with a drought of 23 days. The partial drought of 114 days recorded this year was nearly twice as long as any other in the 29 years, the nearest approach to it being 58 days between October and December 1871. Next to this, but a long way behind it, came April and May 1880, and June and July 1887, each with a partial drought of 41 days, and afterwards June and July 1869, with a period of 40 days. It may be of interest to note that in the course of the whole 29 years there were only five years in which neither an absolute nor a partial drought was reported, and it is rather singular to observe that three out of the five were consecutive. No drought was experienced in London either in 1888, 1889, or 1890. The year with the longest number of absolute droughts was 1880, with four such periods ranging in duration from 15 to 23 days. The longest number of partial droughts was three in the years 1870 and 1884, but in each case the duration was very slightly in excess of the minimum laid down by Mr. Symons in his definition.

In conclusion I have to express my best thanks to the Meteorological Council for their kindness in allowing me to make use of a large quantity of unpublished data. I have further to acknowledge the valuable assistance rendered by my friend, Mr. A. J. Rigby, of the Meteorological Office, who has verified most of the computations.

DISCUSSION.

Mr. G. J. SYMONS said that with regard to the distribution of pressure as indicated in Mr. Brodie's isobaric charts, there was a remarkable similarity between the direction of the normal isobars for the northern part of the British Isles and those shown in the chart for the period covered by Mr. Brodie's paper. He (Mr. Symons) had repeatedly stated that the exceptional features of the past season were almost entirely confined to the southern portion of England, and a line drawn across the country from Falmouth to Boston would roughly cut off the area over which weather of an exceptional character was experienced. It appeared to him very desirable that an investigation such as Mr. Brodie's should be made to embrace the continent of Europe; and indeed it appeared probable that it would be necessary to include the whole of the world, as he knew that in other countries, notably in the United States, weather of very exceptional character had been experienced. It was the duty of meteorologists to ascertain the reason for these remarkable irregularities in the weather, and he hoped that some of the men of ability who were now turning their attention to meteorological problems would be able to devote their time and energies to the work of discovering the cause of such exceptional conditions as those which have prevailed during the present year.

Dr. A. BUCHAN drew attention to the fact that in the southern seas during last spring and early summer icebergs had been seen nearer the equator than had ever been known previously, and it was exceedingly probable that this phenomenon had some connection with the exceptional weather experienced in so many parts of the world. Icebergs had been observed off the Chatham Islands, east of New Zealand, where they had never been seen before. He believed that if a map were constructed showing at as many places of observation over the world as possible, the variations of the actual atmospheric pressure during the past season from the normal, no attempt being made to reduce the pressures to sea level, we should be on the way towards understanding the causes which had been at work in producing the abnormal weather of the present year. With regard to the prevalence of drought, he considered that the distribution of thunderstorms was an important factor in connection with the prevalence of drought, and we had yet to learn why certain districts were more liable to thunderstorms and their attendant rainfall than were others. An examination of the data from Ben Nevis showed that all periods of excess of temperature and great drought occurred with anticyclonic conditions, this fact seeming to point to the existence of an upper stratum of air of higher temperature and greater density than the lower stratum. The weather experienced in the British Islands depended upon the distribution of pressure in their vicinity, the presence of anticyclonic conditions over our islands resulting in the prevalence of magnificent weather, such as had been experienced during the present year.

Mr. B. LATHAM said that the drought had been spoken of as a thing of the past, but it was likely that the community would feel its effects upon water supply for some time into the future. It was curious that the very wet year of 1879 was followed by a year of drought, and if there had been no excess of rain in 1879 England would have suffered greatly from scarcity of water. Similarly, when the drought discussed by Mr. Brodie commenced the springs were very high, probably higher than ever before, the exceptionally heavy rainfall during February having made provision for the period of drought which ensued. Since February, however, the level of water in the springs had been gradually declining, and during the past eight months no rain had passed through his percolation gauge at Croydon. It was a remarkable fact that, in spite of the warmth and dryness of the past season, the amount of evaporation from a surface of water had been much less than usual; and this somewhat unexpected result was, he thought, to be ascribed to free evaporation being interfered with by the film of smoke and dirt which collected on the water surface in dry weather, whereas rainy weather kept the surface clear of these impurities. One of the important lessons learned from the drought had been to discover that, although the rain which had fallen during the period had not percolated through the percolation gauge, it had been sufficient to raise the water level in large reservoirs. He thought that we were now experiencing the lowest water period

of the year, and that if a change did not soon take place the consequences were likely to prove serious.

Mr. C. HARDING said that he had lately been working out the mean summer and winter temperatures and rainfall at Greenwich during the last fifty years, and had also prepared a statement of the number of warm and cold days. These figures showed that in the six months, April to September, of the present year, the temperature was 70° or above on 106 days; in 1865 there were 127 days; while 1846 and 1869 each had 108 days. Temperatures of 80° or above were registered on 29 days in 1898; 1868 had 40 days; and 1846, 1851, and 1859 each had a large number. The mean temperature for the period was 60°·6, the average being 56°·8, or almost 4° less; only two other years, 1865 and 1868, had a mean temperature exceeding 60°. As regards rainfall, the six months' fall amounted to 7·39 ins., the driest year in the fifty being 1870 with 6·80 ins. In 1879, a very wet year, the fall for the six months amounted to as much as 22·03 ins. One of the extraordinary features of the past summer, so far as London was concerned, was the extremely warm night on August 18th, when the minimum temperature at Brixton was as high as 72°. The mean temperature on that day was 81°·2, and was a long way in excess of any mean daily temperature during the past fifty years. The large quantity of ice which had been met with in the South Atlantic was a most interesting feature when considered in connection with recent weather, for such immense bodies of ice would probably exert a considerable effect upon the distribution of pressure, and it was the relative position of areas of high and low barometer that controlled the weather. Another curious fact was that captains of ships crossing the equator had almost all drawn attention to the presence of an easterly current there in the earlier months of the year, such a current in that portion of the Atlantic being quite unknown before.

Dr. A. BUCHAN inquired whether any attempt had been made to eliminate the effect of surrounding hills upon the records of sunshine, as in some localities a considerable proportion of sunlight must be cut off by adjacent hills.

Mr. R. H. SCOTT said that in England and Ireland the places supplied with sunshine recorders by the Meteorological Office were carefully selected in order that the recorder should command a free horizon; and, as far as he recollected, in only two cases, those of Valencia and Llandudno, were the records seriously interfered with by surrounding hills. In his Report on *Ten Years' Sunshine in the British Islands* there would be found a description of the exposure for all the stations included in that Report.

Mr. G. J. SYMONS remarked that it would be a comparatively easy matter to correct sunshine records affected by neighbouring hills. It certainly appeared desirable that something should be done in that direction, but by far the best plan was to select stations for which no correction was required.

Mr. F. GASTER said that, while agreeing with those speakers who had pointed out the desirability of discovering the reason for the abnormalities discussed in Mr. Brodie's paper, he at the same time realised the enormous difficulties which such an investigation involved, and was hardly surprised that nobody had yet ventured to enter upon so great an undertaking. He drew attention to the manner in which the remarkably warm days in April were developed, the exceedingly genial weather at inland places appearing to be entirely due to the intensity of the sunshine, for the temperature of the Easterly current on our coasts at the time was only from 1° to 2° above the average, and people who had gone to the seaside to recruit their health were obliged to remain indoors and have fires lighted because of the keenness of the wind. Inland, however, such was the warming effect of the brilliant sunshine, that it was possible to sit out of doors and enjoy the fine weather. The great dryness of the air was also a very noticeable feature, and one which morning and evening observations quite failed to adequately indicate. In considering the distribution of rainfall, it was necessary to remember that there were three distinct classes of rainfall, viz. 1st., general rain which prevailed with large rain-bearing currents; 2nd, thunderstorm rains, generally very local and the limits sharply defined, so much so that it frequently happened in such cases that the rainfall recorded in London at stations north and south of the Thames differed materially; and 3rd, partial rains falling copiously over large areas of country, rarely accompanied with thunder, and generally occurring with an Easterly wind in summer and a Westerly wind in winter. He had

carefully examined the lists of maximum falls of rain given in Mr. Symons's annual volumes of *British Rainfall*, and found that all of them had occurred with Easterly winds in summer and with Westerly winds in winter. This appeared to him to be a very striking fact, and he thought it would be desirable when discussing rainfall data to classify the figures not according to years but according to the class of rainfall to which they belonged.

Mr. H. SOUTHALL said that in the neighbourhood of Ross the drought was more felt in September than in the earlier part of the year, and he had been told by a farmer that there was practically no grass whatever in that district.

Mr. F. BRODIE, in reply, said that he fully agreed with Mr. Symons and the other speakers who had urged the desirability of discussing the weather over a much larger area than the British Islands, but it was impossible for him to carry out such an investigation, the leisure time at his disposal being so very limited. He had only undertaken the compilation of the present paper because he felt that such a remarkable season should not be passed over without some special notice being taken of it, and as it appeared likely that no one else was doing the work he had undertaken it.

Mr. W. ELLIS, in a communication to the Secretary, said:—It may be of interest to give some particulars for the months of March to June, as observed at the Royal Observatory, Greenwich, in order to show the variation from averages as determined from long series of observations. Four values are in each case given, which will be understood to apply to the months of March, April, May, and June respectively. The mean maximum temperature was 56°·9, 64°·2, 70°·6, and 75°·3, above the average by 7°·2, 7°·0, 6°·5, and 4°·4; the mean minimum temperature was 35°·9, 39°·6, 46°·1, and 50°·1, above the average by 0°·9, 0°·7, 2°·4, and 0°·2; the mean daily range was 21°·0, 24°·6, 24°·5, and 25°·2, above the average by 6°·3, 6°·3, 4°·1, and 4°·2; the mean temperature was 46°·2, 51°·4, 57°·7, and 61°·8, above the average by 4°·5, 4°·2, 4°·6, and 2°·4. The averages referred to are those for the 50 years 1841-1890. The temperature rose to 80°, or above, once in April (80°·0 on April 20th), once in May, and seven times in June, being once above 90° (91°·0 on June 19th). In the 50 years, 1841-90, there is no instance of a temperature of 80° so early as April 20th, the earliest being April 27th, 1865, 81°·5. The rainfall in the four months was 0·433 in., 0·119 in., and 0·530 in., and 0·822 in., below the average of the same 50 years by 1·028 in., 1·542 in., 1·473 in., and 1·200 in., in all 5·243 ins. in defect in the four months. The mean amount of cloud was 4·0, 3·1, 5·7, and 4·8, values all below the average of the 70 years ending 1887; the lowest previous values for this period for March and April being 5·0 in March 1841, and 3·7 in April 1840. The hours of sunshine were 155·1, 61·6 above average, 231·0, 119·5 above average, 186·5, 9·9 above average, and 198·0, 24·7 above average, these averages being for the 15 years 1877-1891. The mean relative humidity was 74, 67, 66, and 65 respectively.

THUNDER AND HAIL STORMS OVER ENGLAND AND THE SOUTH OF SCOTLAND, JULY 8th, 1893.

By WILLIAM MARRIOTT, F.R.Met.Soc.

[Read November 15th, 1893.]

Saturday, July 8th,—two days after the Duke of York's wedding—was a day of remarkable meteorological phenomena, for the temperature over the south and east of England rose above 80°; thunderstorms prevailed over the greater part of England and Scotland; hailstones of immense size fell at numerous places; and squalls or whirlwinds swept up the valley of the Nith and along the coast of Lincolnshire, on the latter capsizing a boat at Skegness whereby 29 lives were lost.

In the morning thunderstorms occurred in Yorkshire and Durham between 6.30 and 11 a.m.; and also over Dorset, Hampshire, Gloucestershire, Worcestershire, and Shropshire between 7 and 10.30 a.m. These storms were not of great intensity.

In Cumberland and the south-west of Scotland severe thunderstorms occurred between 10 a.m. and noon.

About noon a thunderstorm, accompanied by heavy hail and a violent squall of wind, passed over Dumfries and along the valley of the Nith as far north as Closeburn.

The following account is taken from the *Dumfries and Galloway Standard and Advertiser*:—

"About 11 a.m. on Saturday the serenity of the day was sharply and suddenly broken by a thunder shower, which quickly emptied the streets of pedestrians. An hour later, following upon several peals of thunder, there was a strong rush of wind up the valley, from the South-west; and simultaneously with it there occurred a fall of hailstones which were quite commonly the size of large marbles, and fell in such quantities that they lay piled together in little ridges along the foot pavements. Right up from the Solway the path of the wind was marked by overturned stampcoles of hay, and clouds of leaves were driven before it. On Nethertown of Troqueer some thirty ricks were swept before the blast; and on Flatts of Cargen and other farms in the same neighbourhood it played equal havoc with the work of the harvesters. At Cherrytrees persons who were out had to seize hold of a fence to enable them to stand against the force of the wind, and in one field a donkey was pressed by it against the wall. In Dumfries it stripped a number of slates from the roofs; empty boxes which were lying about were swept before it; in Leafield saw mills a long plank was caught and projected to the other side of the workshop; and in Queensberry Square it lifted the covering from the stall of a vendor of crockery. Continuing its frolicsome career north of the town, the blast levelled more than twenty ricks on the farm of Lincluden. On M'Cheynestone and other farms in Dunscore it played similar fantastic tricks; and it strewed the braes of Kirkmahoe and Closeburn with similar tokens of its strength. So suddenly did the storm burst that a number of boys bathing in the Nith at Dumfries were obliged to run up the Sands with their clothes under their arms to find shelter from the pelting of the hail-

stones. The force of the wind here seemed to turn the river and cause it to run up the channel. The hail-shower did not continue for quite a quarter-of-an-hour, but during that time the rattle of the stones upon windows resembled a continuous fusilade of musketry; and in that short space of time it provided a week's work for a good staff of glaziers.

"While reports show that the thunderstorm and accompanying rain were very general over Dumfriesshire and the Stewartry—extended indeed over a great part of Scotland—the hail and wind storm was restricted to a limited area, covering a comparatively narrow band along the valley of the Nith as far north as Closeburn. It is strikingly illustrative of its local nature that while the hailstones caused some injury to the conservatory at Marchfield, there were none at Dalscone, little more than a hundred yards along the same road. On the Lochmaben road the hail was not experienced beyond Brownrigg. The villages of Collin and Locharbriggs lay outside its range, although at Kirkland, Branetrig, and other Torthorwald farms some ricks were overturned by the wind; and on the Stewartry side Lochfoot was beyond the area of the exceptional storm. Many of the hailstones were a peculiar shape, flat and roughly circular, with a white core, surrounded by clear ice, and another white portion forming the outer coating. Their appearance strikingly suggested that of a blind eye. Others were nearly spherical or slightly elongated, like a pigeon's egg. They all showed clearly a composite character, resulting from the aggregation of several pieces of ice. The size varied considerably at different places along the route of the storm. In the neighbourhood of Kirkbean they were relatively small, although, driven as they were by the force of the wind, they were sufficient to prevent horses from facing the storm and to cause their drivers to seek speedy shelter.

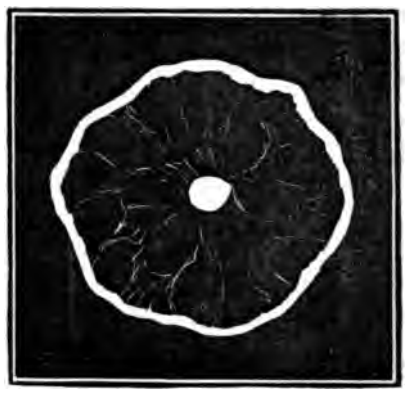


FIG. 1.

Section of Hailstone (actual size) which fell at Dumfries.

"The large hailstones showed a remarkable formation: the nucleus was of opaque white ice about the size of a pea: this was surrounded by perfectly clear ice, the clear ice being apparently an aggregation of separate hailstones closely compacted round the nucleus with a thin coating of white ice; this latter may have been owing to attrition."

At Dumfries they commonly approached the size of pigeons' eggs or good sized marbles. Many measured from an inch to an inch and a half in length. One which was tested was found to be an inch and three quarters in length and seven-eighths of an inch in depth. In another instance where a measurement was made one of the stones was found to be two inches and a half in circumference. A number picked up at random on High Street were found to weigh on an average a quarter of an ounce. Mr. Gibson, grocer, St. Michael Street, who had experience of a somewhat similar storm early in the thirties, states that one placed in his scales was an ounce and a half in weight. In Kirkmahoe the stones seem to have obtained their greatest size. One of circular shape and not

exceptional size measured two inches and a tenth in diameter. Another measurement reported was five and three quarter inches in circumference. Occasional pieces of ice fell of even larger dimension than those regarding which an exact record was kept.

In Dumfries there was a wholesale destruction of glass, particularly of roof lights and of windows where the frontage was to the west, from which direction the storm proceeded when it reached its climax."

Mr. P. Dudgeon, F.R.S.E., of Cargen, has kindly favoured me with a sketch of one of the hail stones (actual size) which he picked up in Dumfries. This is shown in fig. 1.

Peterborough Storm.

The following account is taken from the *Peterborough Advertiser*, July 15th :—

"Shortly before noon on Saturday one of the severest storms ever remembered at Peterborough broke over the city, and did a considerable amount of injuiry. The storm came from the south-east, and was preceded by an insufferable closeness of the atmosphere. For some time before the storm burst an unusual darkness prevailed, while the whole of the south-eastern sky was of a lurid red colour. As the storm approached and the rain began to fall the city became enveloped in a dense mist, while there were frequent and vivid flashes of forked lightning, followed by short claps of crashing thunder. The mist gradually increased in density, so that it was almost impossible to see across some of the streets, and at the same time a violent tempest of wind began to rage. The mist was so dense that the railway signals could not be distinguished, and to prevent accidents the men at the level crossings closed the gates across the road. This was succeeded by the most phenomenal hailstorm ever witnessed in the city. The hailstones descended in clouds, and were of enormous size. Many of them were weighed by Messrs. Heanley and Saunders, and also by Mr. S. Wilson, and were found to weigh about 24 grains each. Many of them measured an inch across, the greater number were lozenge shaped, but others were of a triangular section. The average measurement was from three-quarters of an inch to a half in diameter. The rain also increased and descended in torrents, and what with the gale, which twisted trees about into violent contortions, the rain, the fearful and almost incessant flashing of lightning, followed by the crashing peals of thunder, a scene of unusual wildness was created. The streets were quickly flooded, and there was hardly a house in the city which was not more or less invaded by the rushing water, which hardly fell like rain, but more as if a waterspout were being emptied over the city. The roar of the wind, the rattling of the bullet-like hailstones, the rolling thunder, and the rushing of the water together created such a noise as to drown all else. Fortunately, however, the tempest did not last long.

"At Paston a man took refuge under a tree, but finding the storm increasing with terrific violence, he left the tree and ran to a shed a short distance off. He had no sooner left the tree than a flash of lightning shivered it to pieces from the top to the bottom. Several other trees close to were also struck and dismembered. In many cases where the trees were struck the trees themselves or huge branches were carried by the gale a considerable distance. A brewery chimney in St. Leonard's Street was struck by lightning, and partially destroyed, one of the chimneys at the Great Northern Hotel was also struck by lightning, a chimney at Brook Villa, Brook Street, was struck, and at the house of Mr. Scott, Eastfield Road, the gable end went in, but whether this was caused by the gale or by the violent reverberation of the thunder is not known. A flag-staff over the business premises of Messrs. Hawley, Jermyn, Smith and Co. snapped in two, and carried with it some telephone wires, which had the effect of temporarily blocking the traffic in Narrow Street. Horses and cattle in the streets and in the fields were seen to suffer under the infliction of the hailstorm in a serious manner. As illustrating the stinging force of the hailstones, it may be mentioned that some men got under a tarpaulin at Fengate, but the hailstones inflicted such pain, even through this covering, that the men found themselve

compelled to abandon their tarpaulin for a more substantial shelter. It is also stated that a cart was standing in Cumbergate, and the force of the storm carried it half-way down the street. A large number of minor accidents happened, such as the upsetting of market stalls."

Between 1 and 2 p.m. a thunderstorm accompanied by a squall of wind passed along the Lincolnshire coast, and it was during this squall that the pleasure boat was capsized off Skegness.

From this time onwards till about 10 o'clock in the evening there was a succession of thunderstorms over the north-east of England and south-east of Scotland. From many places it is reported that the thunderstorms were continuous for 9 hours. The barographic traces show considerable oscillations during the whole of this time; so that it is probable that the observers were not able to distinguish between the different storms.

This has been a great drawback in investigating the individual storms, as *time* is a most important factor.

Two storms were remarkable for the immense hailstones which fell during their prevalence over the neighbourhood of Harrogate and Richmond in Yorkshire.

HARROGATE STORM.

The following is taken from the *Ripon Gazette*, July 18th :—

"The severe thunderstorm of Saturday last will be remembered for a long time to come, such a scene as that witnessed on Saturday afternoon not being within the recollection of some of the older inhabitants. At Harrogate the morning was warm and close, and thunder was repeatedly heard in the distance. As noon drew near, the air was very oppressive, and shortly after there was every indication of a heavy thunderstorm. A little before 2 o'clock the sky was thickly overcast with clouds. It was of a peculiar density and unlike ordinary thunderstorms. There was an evenness and almost a murkiness about the tone of the sky which one could hardly fail to remark. Then a blackness nearly approaching that of night descended, and rain became suddenly driven in an oblique direction with terrific force and in phenomenal quantities. The rain soon became thickly mingled with hail of extraordinary size, not to say of a hen's egg or even a cricket ball, as one imaginative writer has stated. The largest that came under our personal observation was 5 inches in circumference, others being 4 and 4½ inches. We have heard of a gentleman who picked one up 2 inches in diameter, and another of 2 oz. weight. On the Moor, we believe, the hailstones were larger than in the town. The rain was accompanied by vivid lightning and loud peals of thunder, and the storm, when at its height, continued from 10 to 15 minutes. During this period extensive damage was done to property in various parts of the town. Trees were blown down and thousands of feet of glass were destroyed. The low parts of the town were flooded for a short time on account of the drains being incapable of taking away the rain, which fell in torrents."

At Brimham Rocks many of the hailstones measured as much as 3 inches in diameter, and at Swincliffe, one was picked up which measured 5½ inches in circumference. I was in Harrogate two days after the storm and had ocular demonstration of its severity, for the majority of the windows having a south-easterly aspect—that is, facing the direction in which the storm came—were broken, as well as skylights and conservatories. Almost without exception in the houses of three floors, all the panes of glass in the top floor were broken, in the middle floor several panes were broken, but on the

ground floor comparatively few panes were broken. There is no doubt that the hail was driven by the wind against the top of the houses with the greatest violence, and consequently most damage would be done there. The top storey panes were mostly small and probably of thin glass, while the ground floor windows consisted of only one or two panes, which were most likely of thicker glass than those above.

The extent of the damage caused by the hail may be gathered from the following note by Mr. J. Farrah, the Society's observer at Harrogate:—

"I have made inquiries amongst the glaziers of this district, and find that in a radius of five miles not less than 100,000 panes of glass were broken, the cost of which is about £3,000. A further £7,000 (taking the same radius) will, so far as I can learn, cover the damage to shrubs, flowers, grass, corn, turnip and potato crops. In this radius comparatively little corn is grown and very little fruit. The greatest acreage is in permanent pasture, from which the milk and butter supply of Harrogate is drawn; otherwise the devastation would have been much greater. I have seen some curious instances of the vagaries of the storm. In one garden the potato tops would be battered to the ground, whilst in an adjoining one they might be comparatively unhurt.

"Harlow Hill, which is situated a mile west of our meteorological station and is 600 feet above sea level, was in the vortex of the storm. The Nursery Gardens there were to a considerable extent wrecked; about 22,000 feet of glass was broken, and a large quantity of tomatoes and herbaceous plants destroyed.

"In the above estimate I have not taken into consideration the damage done by the water to premises where, through one cause or other, it reached the interiors. From my own knowledge this will amount to several hundreds of pounds.

"I was told by a farmer, who lives at Salter-gate Hill, three miles west of Harrogate, that some of the red clay tiles that cover his outbuildings were broken by the hailstones, and that partridges were picked up dead in the fields, having been killed by the same cause."

Dr. H. J. Johnston-Lavis made some drawings of the hailstones, which were published in *Nature*, Vol. 48, p. 294. By permission of the Editor these are shown in fig. 2.

Dr. Johnston-Lavis says:—

"At first a little rain fell, but it was soon mixed with small hailstones, about the size of peas of the usual form. These were quickly followed by hemispheres of the size and character indicated in *C* (fig. 2). After a few minutes they rapidly grew to the size of those shown in *A* and *B*, which were drawn very carefully to actual scale. Most were flattened oval discs, as shown in the two drawings, which exhibit top and side view of one hailstone. I went out myself and measured a good number while they were falling by putting them on a sheet of paper and marking their maximum and minimum diameters. These large stones usually had an opaque spherulitic-like nucleus, followed by two, three, and even a trace of a fourth, clear ice shell intervening with opaque ice. Then followed a broad band of clear ice with a few radiating air cavities, finally enclosed in a mass of white granular feathery ice. The number of alternating laminæ seemed to be irregular, and must have varied with that of the different

vapour strata traversed by each nucleus. The origin of the type (*A* from *C*) is very obvious.

"The quantity that fell was enormous, so that a lawn badly kept was entirely white with the exception of the longer blades of grass that projected. The damage done in the near neighbourhood must amount to some thousands of pounds, and very few were the houses in this town that escaped without windows being broken."

FIG. 2.

Sections of Hailstones (actual size) which fell at Harrogate.

RICHMOND (YORKS.) STORM.

The following account is taken from *The North Star*, July 10th:—

"Shortly after 2 o'clock on Saturday afternoon, Richmond and district was visited by a thunderstorm the violence of which has had no equal within the memory of the oldest inhabitant. During the morning the atmosphere was sultry, almost suffocating, and thunder was heard at intervals rumbling in the distance. About 2 o'clock the air became misty, and the peals of thunder were more audible. A few minutes later the sky all round was black, darkness set in, and the terrible storm began. Rain drops as large as a crown piece fell at first. These were succeeded by small hailstones, which rapidly increased in size until they became as large as bantam's eggs. A wind rose at the time, and these large missiles fell in a perfect deluge. A scene of the wildest confusion followed in the

Market Place, for the market folk had not then started on their homeward journey Women and children screamed with fright, and ran into the nearest shops for shelter; but these did not afford them much protection, for the enormous pieces of ice shot through the windows like cannon balls. With such force did they fall that pots and ornaments on the opposite walls were smashed to pieces. The rattling of falling glass and pots, the vivid flashes of the lightning combined with the screams of the women and children and the heavy peals of thunder, formed a scene which will never be forgotten by those who witnessed it.

"Some of the pieces of ice were of very artistic shape. Others were round, two inches in diameter, and a quarter of an inch thick. These tapered in picturesque curves to a point in the centre, and the round edges looked as though they had been skilfully carved. Some were two inches long, half-an-inch in diameter, and were prettily marked, while others were simply blocks of ice of all sizes and descriptions. Some of these, which were weighed by many for curiosity, turned the scale at three and a half ounces.

"The damage done is enormous, and very few houses in the town have escaped without broken windows, while in many of the large houses not a single window remains unbroken. Most damage has been wrought among the greenhouses and the studios of the photographers. The conservatories at Bolton Crofts—Alderman Roper's, Dr. Carter's, and others—were all riddled through and through. The houses where windows faced the south and east suffered most. The bulk of the damage was done in Frenchgate, Millgate, Market Place, and Newbeggin. Skylights were shattered and fell crashing to the ground, greatly alarming the inhabitants. The studios of Messrs Riley, Metcalfe, and Sanderson, were wrecked.

"In the King's Head Hotel, no less than 175 panes of glass were smashed; at Mr. T. McGuinness's there were 147, and at the Wesleyan Chapel, there were 185 broken. At the Newbeggin side of the Roman Catholic Church, numbers of the small diamond-shaped windows were riddled through, and those in the Primitive Methodist Chapel were shattered. The sky-light over the magisterial quarters of the Town Hall, which is of very thick glass, was smashed to pieces. Considerable damage has been done to garden produce. Apples, plums, gooseberries, and currants were cut to pieces and strewed over the land. Small branches and leaves were cut off the trees, and the Queen's Road after the storm presented the appearance of a green field.

"The pieces of ice could be picked up in shovelfuls, and many of the houses were flooded. All the damage was wrought within the space of ten minutes"

I visited Richmond on August 17th, nearly six weeks after the storm, and from what I saw and heard I do not think that the above account is at all exaggerated. The storm came up from about south-east at 2.20 p.m., and was accompanied by a strong wind. The air was also very thick, being described "as dark as pitch." The hailstones were first about the size of marbles, and these were succeeded by the very large ones. All windows facing east to south were broken. The violence of the wind and the force with which the hailstones fell was clearly demonstrated by both glass and hailstones being hurled from the windows to the opposite sides of the rooms, and in one instance, which I measured, 25 feet along a passage. I was informed that a military officer saw the hailstones rebound to a height of 20 feet. I measured a tile ¾ inch thick, which had been broken by the hail, the fracture being 8½ inches in diameter.

As hail fell at Bedale a short time before that at Richmond, it seems that the storm was developed a little distance south-east of Bedale, and that it increased in energy as it travelled along, and that its fury was not spent until it had swept beyond Richmond. The width of the storm was from two to three miles.

Nearly every one in Richmond was terribly scared by this storm, and

many thought the world was coming to an end. There was one person, however, who did not lose his presence of mind, and that was Mr. H. J. Metcalfe, who collected a number of the hailstones, and succeeded in getting two photographs of them, actual size.[1] These are most interesting and instructive, as they show not only the shape and the size of the hailstones, but also in several instances their structure.

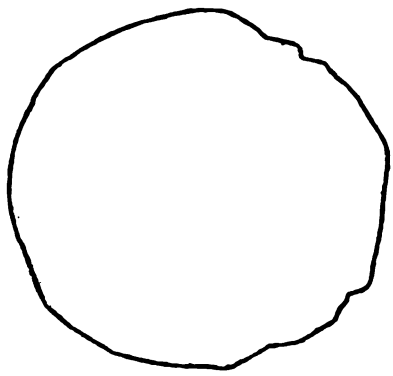


FIG. 8.

Outline of Hailstone (actual size) which fell at Belleisle, Richmond, Yorkshire.

Mr. M. Cooper, of York, made a drawing of two hailstones which he picked up in a bed room at Belleisle, about half-a-mile out of Richmond. The one shown in fig. 8 had been in the room some time before it was found, and consequently was reduced in size.

OTHER STORMS.

Between 4 and 5 p.m. violent hailstorms occurred in the neighbourhood of the Rivers Ouse and Wharfe. Large hailstones fell at Goole, Howden, and Selby, while at Snaith they are described as being "as large as plums," and at Tadcaster "as large as marbles."

During the afternoon a violent thunderstorm passed in an almost straight line from Normanby to beyond Darlington, that is to say from south-south-east to north-north-west. Its path, which followed very closely the main line of the North Eastern Railway, was clearly indicated by persons and cattle being struck by lightning.

A number of thunderstorms prevailed over the south-eastern counties during the afternoon. These travelled mostly in an easterly or north-easterly direction. Some hail fell at Crowborough.

A succession of violent thunderstorms also passed over the north-east of England and the south-east of Scotland during the afternoon and evening.

In the evening about 10 p.m. a thunderstorm passed along the north-west coast of England, which was accompanied by heavy rain.

[1] These photographs are given in the Hon. Rollo Russell's book *On Hail*, London, 1893.

Barometrical Pressure.

From the *Daily Weather Report* at 8 a.m. it appears that there was a depression lying over the west of Ireland, the lowest barometer reading being 29·58 ins. at Valencia. The pressure increased to 30·0 ins. and upwards over nearly the whole of Scandinavia, Denmark and Germany, as well as in Spain, and to 30·1 ins. and upwards in the north of Norway. The gradients were consequently slight for Southerly and South-easterly winds.

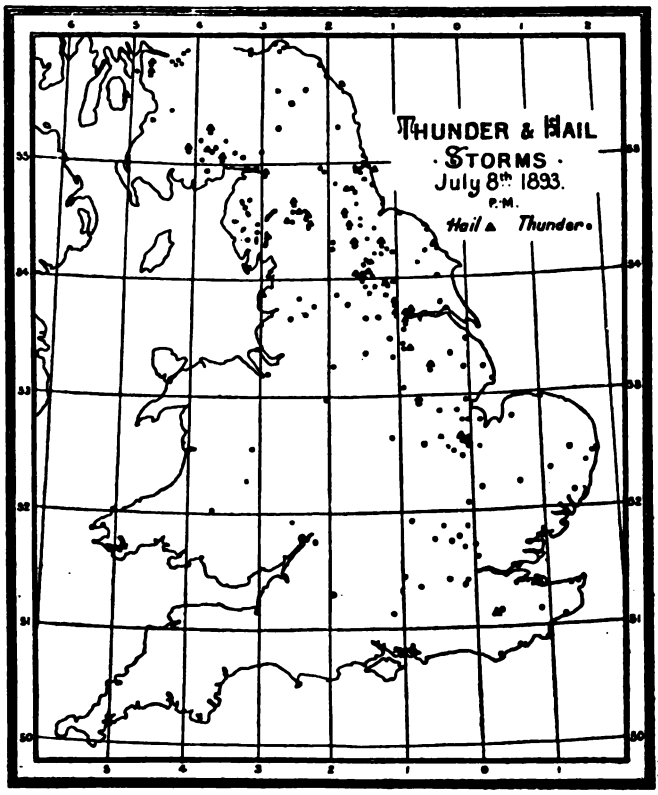


Fig. 4.

I endeavoured to prepare hourly charts from 8 a.m. to midnight, showing the distribution of pressure and the direction of the wind. I was not, however, successful, as the data available were insufficient for the purpose. By plotting on charts the changes in pressure from hour to hour, it appeared that the barometer was falling steadily over the greater part of England, but in Yorkshire and the south of Scotland considerable changes in pressure occurred, these changes being greatest and most numerous at the times of the occurrence of the thunderstorms. The barograph traces exhibited considerable oscillations at the times of the passage of the thunderstorms, that at Leeds (fig. 5) showing a remarkable rise of ·06 inch between 1 and 2 p.m., which was no doubt connected with the Harrogate storm.

Rainfall.

Rain fell over the whole of England and Wales and the south of Scotland during the day; the amounts over the southern half of England were generally under a quarter of an inch. Over the north of England and the south of Scotland the rainfall for the most part exceeded half-an-inch; while along the north-east coast and part of the north-west coast, the north-west of Yorkshire, Durham, Northumberland, and part of the south-west of Scotland the rainfall was over an inch. At Durham the rainfall amounted to 2·42 ins.

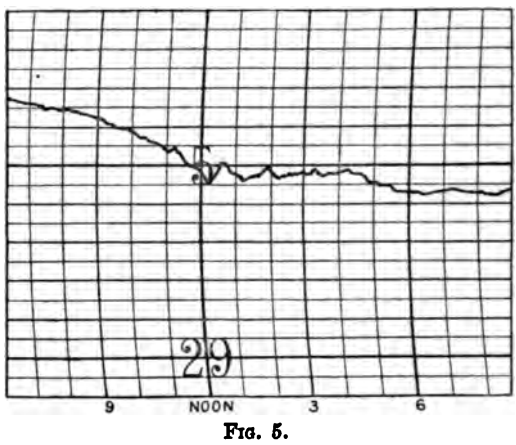


Fig. 5.

Barograph trace at Leeds, July 8th, 1893 (The clock was about 20 minutes slow).

Paths and Rate of Travel.

The storms in the northern part of the country travelled generally in a north-north-westerly direction at the rate of about 20 miles an hour. They appear to have taken the path of the least resistance, and consequently passed over low ground and along the river valleys and the sea coast. Several storms seem to have followed each other along the same track.

Lightning.

The lightning in some of the storms was very destructive, many persons and animals being killed. There are two cases which I wish to mention.

The first is that of a man named Rudd, at Harrogate, who had the crown completely taken out of his hat, though he himself was uninjured. The second is that of a man on a haystack who, when struck by lightning, was *lifted up* in the air, and then carried out against the wind, and fell to the ground like a stone. As this may have been the result of a discharge from the earth to the cloud, or what is sometimes called an "upstroke," I think it desirable to give the following report of the inquest from the *Peterborough Advertiser*, July 15th.

"Whittlesey. A Man Killed By Lightning.—During the great storm on Saturday William Smith, landlord of the 'Cross Guns,' was putting a tarpaulin on a haystack with two other men, when all three were struck by lightning, and

Smith unfortunately was killed. An inquest was held at the 'Cross Guns' Inn, on Monday, by Mr. G. Carrick, deputy-coroner, on the body. Mr. E. C. Elderkin was foreman of the jury, The first witness was Samuel Lyon, labourer, who stated: I lived at Stowe, but at present am working for Mr. Keeble on his farm near the 'Cross Guns' Inn. I knew deceased and indentify the body just viewed by the jury as that of William Smith. He was I believe 48 years of age. On Saturday last I was working on Mr. Keeble's farm, and the deceased was working with me about a quarter to two in the afternoon. He and I were on the top of a haystack and a thunderstorm appeared to be coming up. We were engaged covering the stack with sheetings. Whilst so engaged a flash of lightning played round about us. The shock brought me on my knees. I was just speaking to him, and all of a sudden he appeared to be lifted off the top of the stack and fell on to the ground, at a distance of about 25 feet. The sheeting on the top of the stack was smoking as if struck by lightning. When the deceased fell I at once went to him. He was lying stretched out on the ground. The cloth cap now produced I saw about a yard from the deceased. It is rent open from the top to the edge. It has a slight mark as if of burning upon it. When I went up to him I undid his shirt collar and lifted him up. He gave no sign of life. I believe he was then dead.—Gideon Infield stated: I am a farmer and live at Ramsey, Hunts. On Saturday last, about a quarter to two, I was engaged carting hay for Mr. Keeble near the 'Cross Guns.' I was near the hay stack referred to by last witness, and he and deceased were upon the stack covering it up with sheeting, but had not then done so. I had just finished my dinner, when a thunderstorm, accompanied by a high wind, came on. A flash of lightning passed me, which was immediately followed by another flash and a very loud peal of thunder. The second flash went in the direction of the deceased, and I saw it strike him at the back of the head, and the shock brought Lyon on his hands and knees, on the top of the stack. I saw the cloth cap now produced, and which deceased was wearing on his head when he was struck. The deceased was lifted up about 4 to 5 feet in the air in a perpendicular direction, and was then carried out against the wind for 8 or 10 yards, away from the stack, and fell to the ground like a stone. I was about 60 yards from the place, but hurried up to the deceased, who was lying stretched out on the ground. He never moved again. His pulse gave no sign of life.—Arthur Jordan Vialls stated: I am a police-constable in the Isle of Ely force, stationed at Coates. On Saturday afternoon last the death was reported to me of the deceased. I at once went to Keeble's farm, where I saw the dead body. I found a mark on the right side of the neck similar to that of a burn. It appeared to be recent. I examined the shoulder and chest without removing all the clothes, but saw no other marks or bruises. I saw the cloth cap which I now produce. It was lying on the deceased's face, and was in the same condition as it is now. It has a rent from the button on the top down the back to the edging.—A verdict was returned that deceased was accidentally killed by lightning. The only mark on deceased was the slight burn on the neck."

FORMATION OF HAIL.

In the drawings and photographs of the sections of the hailstones, there are several alternate coatings of opaque and clear ice. These coatings must be due to the revolutions accomplished by the hailstone which was probably drawn in towards the vortex of the storm several times. Ferrel, in his *Popular Treatise on the Winds*, gives the following explanation of the formation of hail (p. 423):—

"The origin of the hailstone is often not a rain drop, but a bunch of snow formed in the snow region, and moistened by the rain carried up into this region before it has had time to become frozen into hail. This moist snow is kept up there until it freezes, and after that, while being kept up there, and after it commences to fall, so long as its temperature remains below zero it continues to receive a coating of ice from the rain which is carried up past it and that through which it falls. As it grows and is carried outward above where the ascending current is weaker, it finally becomes too heavy to be kept sus-

pended in the air, and falls to the earth a hailstone, with a *kernel of frozen snow in its centre.* In such a case we may imagine the soft ball of snow to have originated in the snow region at *m* (fig. 6) and then to have been kept partially suspended and to have been carried up and out slowly from the centre to a distance where it could drop down, having become meanwhile reduced to a low temperature, and that on its way down it received a coating of ice from the small ascending rain drops, or others with which it came in contact during its fall, and that it finally reached the earth at *n*.

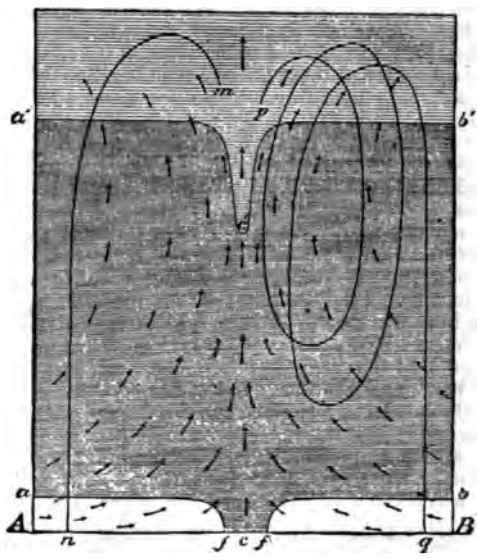


FIG. 6.

Ferrel's Theory of the Formation of Hail.

"It often happens, however, that in falling very gently where the ascending current at no great distance from the vortex is not quite, but nearly, sufficient to keep it suspended, it is drawn in again by the indrawing currents from all sides towards the vortex, as the scud clouds under the rim of the tornado cloud, where the ascending current is sufficient to carry it up again into the snow region, where it receives a coating of snow moistened by the small rain drops carried up into the snow region before they freeze. This coating now becomes frozen solid, and the whole mass, it may be, reduced considerably below zero temperature before it is carried out above, where it can gradually drop down again toward the earth; and in falling, even through the lower part of the snow region where there is little snow, but mostly rain drops not yet frozen, it receives another coating of solid ice; for its temperature having been reduced considerably below zero, it continues to freeze the rain coming in contact with it for a long distance after having passed down into the cloud region. But in gently falling down it may be drawn in a second time towards the centre and be carried up by the ascending current into the snow region and receive another coating of solid ice in the same manner as before. This process may be repeated a number of times, in each of which the hailstone, disregarding its gyratory motion all the while, describes a kind of orbit not returning into itself, somewhat as represented in fig. 6, until finally it is carried out above so far from the centre, or the strength of the tornado becomes so much weakened, that it is no longer carried in toward, and up in, the central part, but falls to the earth a *hailstone with a snow kernel and a number of alternating concentric coatings of solid ice and frozen wet snow.*

"In this case we may suppose the small snowball to have originated at *p* and to have been carried up and out, and then to have fallen down and to have been drawn in toward the centre several times, until finally it was carried out so far, and had grown to be so heavy that it was not brought in toward the centre, but dropped down to the earth at *q*."

The above explanation seems to account for the numerous alternate coatings of opaque and clear ice in the large hailstones. In each of the storms in which hail fell, the same characteristics were reported, viz. great darkness, squall of wind, severe thunderstorm, and heavy rain. All these seem to show that the air was in violent agitation favourable for the production of large hailstones.

In conclusion, I would remark that the results of this investigation confirm those set forth in my "Report on the Thunderstorms of 1888 and 1889."

THE GREAT STORM OF NOVEMBER 16th-20th, 1893.

By CHARLES HARDING, F.R.Met.Soc.

[Read December 20th, 1893.]

The storm which forms the subject of this paper was so disastrous both with respect to loss of life and property on our seas, as well as having occasioned considerable loss and suffering on shore, in addition to the vast destruction of timber, especially over the northern portion of the Kingdom, that it seems desirable that some account of its occurrence should appear in the *Quarterly Journal* of the Society.

For a few days prior to the storm a large area of high barometric pressure spread from the neighbourhood of Iceland, over Great Britain and the North Sea, to central Europe. This high pressure system moved steadily to the south-eastward, while a small disturbance reached us from the Atlantic and advanced eastwards up the English Channel and to Germany during November 14th and 15th.

This pilot disturbance caused a partial giving way of the high pressure area over western Europe, but on November 16th high barometer readings had again asserted themselves over Russia, and doubtless the re-establishment of anticyclonic conditions over central Europe had a most important influence on the track of the storm, which was at that time within so short a distance of our western coasts.

The earliest intimation of the approach of bad weather, in connection with the storm which forms the subject of this paper, was shown at Valencia at 4 p.m. on the 15th, when the barometer commenced to fall and the wind an hour or so afterwards began to freshen from the South-east. The Meteo-

rological Office, in its remarks prepared for publication in the next morning's newspapers, reasoning on the telegraphic reports made on the 15th at 6 p.m., said: "The high pressure area over England and the North Sea is moving eastwards, and new low pressure systems seem to be advancing from the westward." At this time the central area of the approaching storm system was about 500 miles to the south-west of Valencia.

At 8 a.m. on the 16th the barometer at Valencia had fallen to 29·42 ins., which was a fall of 0·48 in. since the previous day; and the North-easterly wind which had been blowing over the British Islands had given way entirely to a warm and humid South-westerly current of air, under the influence of the large disturbance which was rapidly approaching our shores from the westward. The telegraphic reports received by the Meteorological Office did not show a stronger force than a moderate gale (7 of Beaufort's Notation), and that force was only attained at Valencia, Roche's Point, and Scilly. The gradient for Southerly winds at 8 a.m. was 0·6 in. in 460 miles.

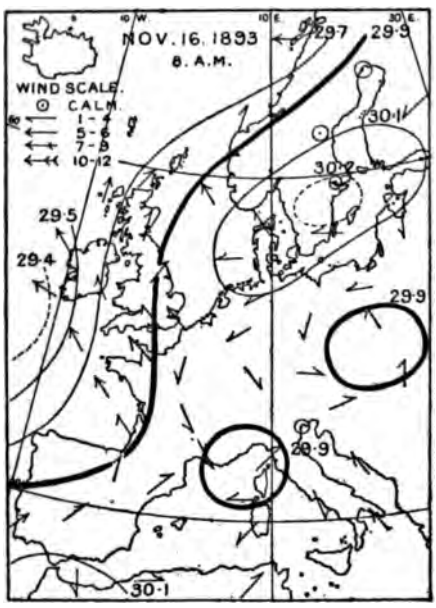


FIG. 1.

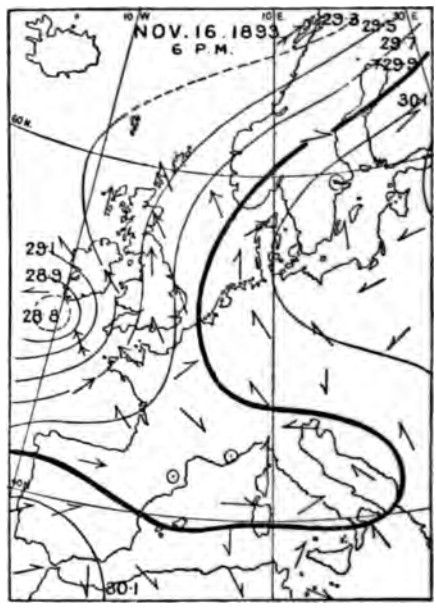


FIG. 2.

At noon the Barque *Ariel*—Captain U. S. Goldsmith—keeping a log for the Meteorological Office, was near the centre of the disturbance. The lowest reading of the barometer occurred at this time, and the wind is reported as calm. The vessel at noon was about 300 miles west of Valencia, and the captain afterwards reported a heavy North-westerly gale lasting about 8 days.

The 2 p.m. reports showed that a strong gale was blowing at Scilly, and a fresh gale at Valencia from South-east, while the barometric fall had extended over the whole Kingdom.

At 6 p.m. the central area of the storm was within a few miles of our extreme south-west coasts, and in the south of Ireland the barometer had fallen to 28·8 ins.; while on our south-east coasts it was nearly an inch higher. The gradients for South and South-west winds had therefore considerably increased since the morning, and gales or strong winds were now blowing over the whole of the British Islands.

The lowest barometer occurred at Valencia at 7 p.m. on the 16th, and the wind shifted from East by south to West-south-west between 8 and 9 p.m.

At 8 a.m. on the 17th the central area of the storm was situated over the west of Scotland, the lowest barometer reading being 28·53 ins. at Ardrossan. The storm had traversed Ireland at the rate of about 24 geographical miles per hour, passing from south-west to north-east during the preceding night; and the winds at all the Irish stations had shifted to the North-westward and had generally moderated in force. During the night and early morning a heavy gale was experienced over Ireland and in the north of Scotland, as well as at many places in England. The greatest difference of barometer readings in a given distance was now in the rear of the storm, where a rapid recovery had set in.

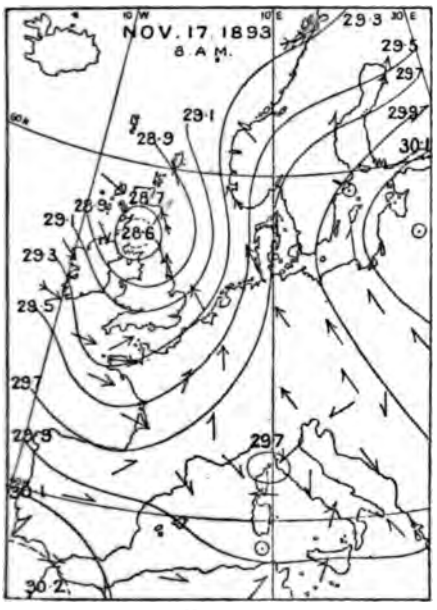


FIG. 3.

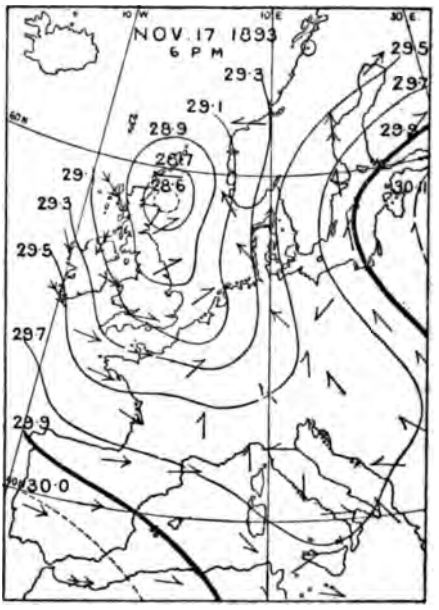


FIG. 4.

At 2 p.m. the centre had traversed Scotland, and was situated close to the eastward of Peterhead. The anemometrical records at Aberdeen show a shift of wind from South by east to West by north between 1 and 2 p.m.

The winds had become North-westerly over the greater part of England, while the steepest gradients were in the south-western segment of the storm area and for decidedly North-westerly gales.

The 6 p.m. observations showed that the central area of the storm was close to the eastward of Wick, where the barometer was 28·57 ins., and a moderate gale was blowing from the North. The gradients for North-westerly winds were still very steep, the difference of the barometer from Wick to Valencia amounting to an inch. The North-westerly gale was very strong, but winds had lulled considerably over the eastern portion of the Kingdom, where subsidiary disturbances were very prevalent. The north-westerly gradient extended from Wick to the south of Spain.

The anemograms at Deerness, Orkney, show that at 6 p.m. the wind shifted from East by north to North by east, and the velocity increased very suddenly.

At 8 a.m. on the 18th the storm system had taken a very sudden and abrupt change in its path, and was now travelling south-eastwards, skirting

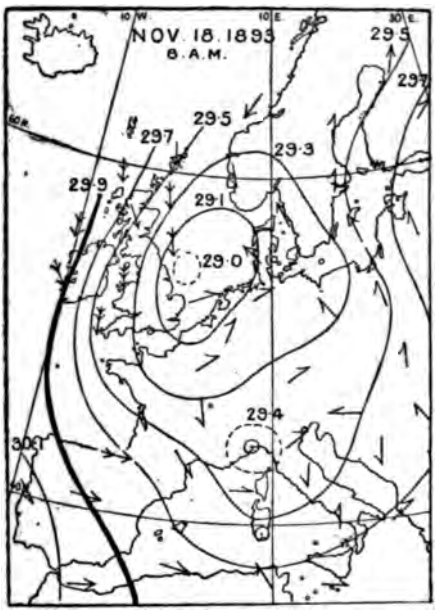


FIG. 5.

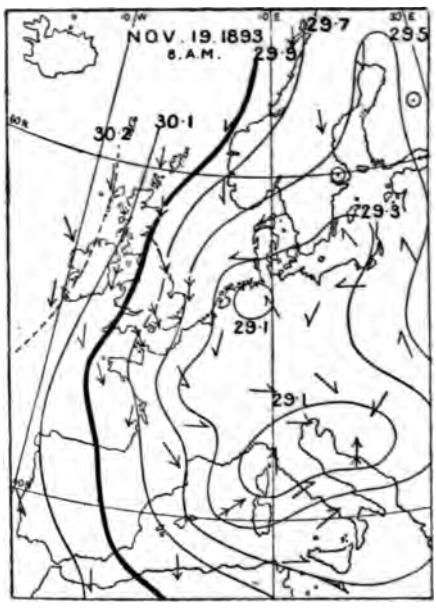


FIG. 6.

close to our east coasts. The centre was situated in the North Sea about 50 miles to the east of Scarborough, but the disturbance was gradually filling up, the lowest barometer reading being 28·99 ins. at Spurn Head. The gradients for Northerly winds were the steepest, the difference of barometer reading amounting to an inch between York and Valencia. Gales occurred in the preceding night over nearly the entire Kingdom, and were exceptionally severe over Scotland and very heavy over Ireland.

The self-registering records at Aberdeen indicate that the centre of the storm area repassed that station on a south-easterly track between 9 and 10 p.m. on the 17th. It passed Alnwick Castle about 1 a.m. on the 18th.

At 2 p.m. the central area of the disturbance was still situated off the south-

east coast of England, the lowest barometer reading being 29·08 ins. at Yarmouth. Gradients were steep over the entire Kingdom for Northerly winds, and gales were blowing over nearly the whole of the British Islands. The barometer was now rising in all parts of the country.

The 6 p.m. observations showed that the centre was continuing its passage to the south-south-east, and was now situated over Belgium. Strong Northerly gales were still prevalent over the United Kingdom, and the wind had increased in force over the south-east of England. The difference of barometer readings between Valencia and the coast of Kent was rather more than an inch.

At 8 a.m. on the 19th the disturbance had again taken rather a different course, and was travelling east-south-eastward ; the centre lay now close to Cuxhaven, where the barometer was reading 29·10 ins.

Northerly gales continued to blow on most of our coasts, but the gradients were becoming less steep over the western portion of the Kingdom ; they were, however, still steep over the south-east of England, and were accompanied by strong Northerly gales.

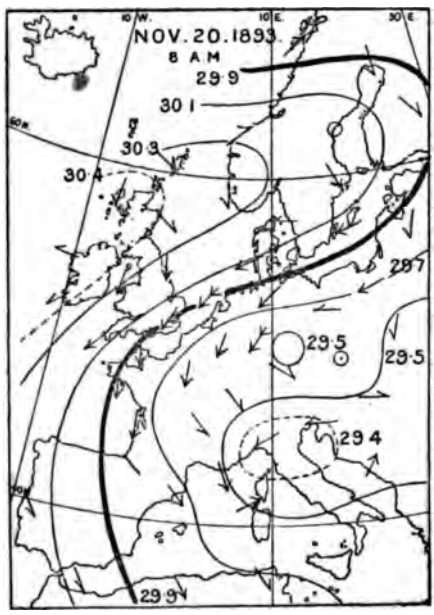


FIG. 7.

On the 20th the gradients were steep for Northerly winds, but the gales were generally subsiding, although still blowing strongly on our south-east coasts, and at Yarmouth the highest wind velocity throughout the gale was attained at 5 a.m.

The anemograph records, kindly supplied by the Meteorological Council, have been tabulated for a period of 4½ days, and are given for 16 different stations over the United Kingdom in Table I. They show that the hourly

TABLE I.—WIND VELOCITY IN MILES PER HOUR, NOVEMBER 16TH–20TH, 1893.

Hour.	Valencia.	Dublin.	Armagh.	Orkney.	Aberdeen.	Glasgow.	Alnwick Castle.	North Shields.	Fleetwood.	Liverpool.	Holyhead.	Yarmouth.	Greenwich.	Kew.	Falmouth.	Scilly.
16th.																
10 a.m.	33	16	26	23	17	10	17	26	21	18	32	31	10	15	30	46
11 ,,	39	14	21	25	20	11	20	24	21	22	25	30	14	18	30	51
Noon	46	12	23	29	22	12	21	23	23	27	31	29	12	20	30	53
1 p.m.	44	13	27	26	23	11	15	24	32	29	36	29	17	15	30	55
2 ,,	46	14	24	29	24	9	21	25	33	35	34	32	13	19	35	51
3 ,,	40	22	26	28	24	16	18	27	31	32	26	37	13	17	37	48
4 ,,	36	21	24	31	27	15	25	33	29	37	25	36	10	11	40	47
5 ,,	26	23	24	30	29	13	23	34	39	39	25	41	7	15	36	47
6 ,,	9	18	23	38	26	9	37	31	38	42	34	43	10	19	38	42
7 ,,	3	24	16	39	30	14	30	33	39	47	46	42	16	19	37	40
8 ,,	6	28	15	36	29	17	30	36	43	42	51	39	14	23	37	36
9 ,,	17	24	17	35	24	19	36	35	44	44	54	43	16	21	38	34
10 ,,	33	19	18	35	29	19	28	34	40	44	64	43	17	19	38	31
11 ,,	40	11	20	35	28	13	37	34	49	41	60	45	14	22	38	32
Midnt.	37	10	20	34	28	18	34	31	52	44	61	41	15	20	33	32
17th.																
1 a.m.	38	18	13	35	26	12	33	32	54	33	60	45	20	23	36	
2 ,,	30	15	10	34	32	15	27	34	50	35	58	44	15	21	30	
3 ,,	31	17	7	33	27	19	40	40	47	34	60	41	17	17	30	
4 ,,	28	21	11	36	34	17	29	39	41	28	38	33	16	22	28	
5 ,,	35	17	12	40	31	18	35	36	44	23	43	36	16	21	27	
6 ,,	45	18	14	41	32	15	32	37	37	27	31	33	17	20	29	
7 ,,	52	17	14	36	39	7	32	40	40	28	39	30	17	23	29	
8 ,,	50	16	15	34	35	8	37	43	40	30	28	30	22	19	29	
9 ,,	52	19	19	30	34	10	23	47	42	26	32	24	19	20	29	
10 ,,	49	18	19	26	29	20	32	41	39	30	32	24	17	19	26	
11 ,,	44	17	16	23	29	24	26	44	36	37	40	22	18	22	27	
Noon	49	17	15	27	24	27	34	32	38	35	40	17	22	23	45	Clock stopped.
1 p.m.	48	19	15	23	8	25	44	35	44	33	41	16	22	23	44	
2 ,,	45	18	17	20	26	14	43	29	39	32	32	16	21	24	40	
3 ,,	50	14	16	15	22	18	41	25	35	35	29	12	22	24	34	
4 ,,	50	20	17	13	17	21	28	25	31	34	31	11	22	20	29	
5 ,,	50	18	14	14	14	14	26	24	31	25	30	14	14	18	27	
6 ,,	52	22	16	46	12	11	16	17	24	26	28	17	19	28	23	37
7 ,,	53	19	18	81	11	9	15	18	18	17	48	14	31	19	22	34
8 ,,	45	19	23	86	16	10	7	8	9	10	52	15	29	15	26	48
9 ,,	41	21	23	96	21	21	5	5	14	12	58	25	20	14	37	51
10 ,,	51	20	29	95	29	30	6	6	14	7	61	23	19	14	44	53
11 ,,	53	23	24	93	39	39	12	10	25	5	59	22	20	14	42	55
Midnt.	57	21	27	91	44	37	15	9	24	12	68	16	18	16	35	58
18th.																
1 a.m.	52	24	24	90	46	41	25	15	28	13	70	14	15	16	44	60
2 ,,	54	23	26	86	45	33	22	26	31	26	81	11	16	16	48	66
3 ,,	58	21	27	82	39	44	30	31	42	24	85	8	15	19	46	65
4 ,,	60	21	30	80	42	43	30	32	40	28	78	8	14	9	44	61
5 ,,	54	21	31	76	44	31	28	32	50	27	80	9	10	4	45	61
6 ,,	54	28	28	74	41	35	30	37	52	30	80	9	8	4	49	66
7 ,,	52	24	30	70	40	32	36	51	53	40	81	6	8	5	49	63
8 ,,	41	31	25	65	41	28	36	67	63	49	84	6	7	7	50	59
9 ,,	48	33	27	64	37	33	39	69	83	49	88	6	8	8	53	60
10 ,,	45	31	25	65	40	27	30	69	87	44	87	4	10	11	55	59
11 ,,	40	35	20	59	38	38	38	68	79	49	89	4	9	16	54	53
Noon	50	32	21	59	36	29	35	64	80	45	79	3	8	13	53	58
1 p.m.	52	35	23	59	34	29	26	64	82	46	80	10	14	15	52	57
2 ,,	42	29	15	54	30	33	34	59	70	42	84	8	15	18	52	54
3 ,,	43	20	15	53	33	29	26	63	77	41	79	5	18	24	53	51
4 ,,	43	10	15	54	31	27	26	58	71	43	71	3	24	26	50	50
5 ,,	42	14	17	55	27	14	29	51	70	42	74	6	26	30	51	51

TABLE I.—WIND VELOCITY IN MILES PER HOUR, NOVEMBER 16th–20TH, 1893.
Continued.

Hour.	Valencia.	Dublin.	Armagh.	Orkney.	Aberdeen.	Glasgow.	Alnwick Castle.	North Shields.	Fleetwood.	Liverpool.	Holyhead.	Yarmouth.	Greenwich.	Kew.	Falmouth.	Scilly.
18th.																
6 p.m.	44	13	15	56	29	17	29	48	64	44	70	8	35	31	39	55
7 ,,	51	13	12	51	29	14	22	43	70	43	64	23	33	38	47	57
8 ,,	39	7	15	55	29	15	27	43	69	39	66	48	35	32	31	52
9 ,,	39	4	10	59	25	11	23	38	65	40	59	42	34	34	36	58
10 ,,	39	9	14	52	27	11	24	38	62	38	65	40	32	32	26	55
11 ,,	42	9	17	54	29	17	23	35	60	36	62	36	29	29	28	49
Midnt.	44	10	15	54	29	18	25	37	55	34	68	41	31	31	26	47
19th.																
1 a.m.	38	7	14	55	26	23	21	36	62	35	68	48	33	30	25	46
2 ,,	43	8	11	51	24	16	23	35	55	38	63	44	33	31	24	46
3 ,,	39	7	9	56	22	15	25	36	48	33	67	43	33	33	25	47
4 ,,	33	9	9	53	29	20	23	34	55	35	60	39	33	33	25	44
5 ,,	32	13	9	49	25	17	20	31	56	36	65	45	33	30	26	46
6 ,,	33	11	11	47	24	20	21	38	52	34	60	35	33	33	28	43
7 ,,	32	7	11	51	26	17	21	38	54	34	69	33	26	31	26	42
8 ,,	35	5	11	48	26	13	24	47	53	39	65	37	31	30	23	41
9 ,,	32	6	9	47	30	14	21	45	61	39	66	36	30	31	27	43
10 ,,	33	8	10	44	29	11	22	44	58	35	65	34	29	31	29	36
11 ,,	22	10	10	37	25	13	26	44	56	35	68	43	31	34	34	40
Noon	25	15	13	39	20	17	21	48	51	32	67	36	34	32	29	38
1 p.m.	19	16	14	39	19	19	26	40	47	34	60	26	32	29	29	37
2 ,,	19	15	13	33	17	16	25	44	57	36	64	20	28	27	27	36
3 ,,	17	16	11	29	19	18	21	41	53	36	58	29	27	28	28	40
4 ,,	20	13	10	31	17	21	19	36	42	34	58	26	24	25	22	36
5 ,,	18	11	9	31	18	13	26	32	56	33	62	38	20	17	18	34
6 ,,	23	11	7	31	17	15	28	28	58	31	56	45	19	23	24	33
7 ,,	25	10	6	25	18	17	21	29	44	31	52	42	22	23	29	33
8 ,,	18	12	6	24	15	11	22	26	42	30	57	45	29	27	29	34
9 ,,	24	15	7	22	16	15	25	25	50	25	55	50	28	33	27	35
10 ,,	35	14	10	20	17	12	27	28	47	19	51	50	31	33	25	33
11 ,,	27	11	8	20	13	16	22	22	41	21	51	46	30	31	30	33
Midnt.	18	11	7	16	14	11	17	22	39	22	50	53	33	29	27	32
20th.																
1 a.m.	11	11	8	16	16	10	20	23	43	18	53	52	28	28	19	31
2 ,,	9	12	8	13	13	9	23	24	41	23	55	54	30	29	21	29
3 ,,	9	13	7	13	11	9	16	19	35	17	51	58	30	30	20	27
4 ,,	4	12	7	13	15	12	18	22	37	16	50	60	30	30	20	25
5 ,,	7	12	6	17	15	13	20	25	38	20	50	64	32	30	17	23
6 ,,	8	15	6	15	11	10	20	24	35	17	48	63	30	28	15	22
7 ,,	11	11	5	10	12	14	23	26	36	18	48	57	29	29	16	22
8 ,,	12	10	6	10	12	14	17	21	35	21	45	60	25	28	19	21
9 ,,	15	9	5	9	11	11	25	25	36	19	48	62	29	31	17	22
10 ,,	12	10	7	7	11	11	29	24	28	22	47	56	32	29	19	21
11 ,,	15	11	9	6	11	13	32	20	28	18	45	57	32	33	23	24
Noon	16	13	11	8	11	11	25	28	25	20	49	57	32	30	24	22
1 p.m.	17	12	10	5	8	15	32	31	27	22	49	58	32	31	23	22
2 ,,	22	12	11	7	11	15	27	29	23	23	42	57	35	25	24	22
3 ,,	18	13	10	8	11	13	21	24	25	27	33	57	33	29	21	22
4 ,,	11	14	10	7	11	12	22	22	17	27	40	53	29	26	20	22
5 ,,	12	12	7	7	11	8	22	23	11	20	35	49	30	28	17	23
6 ,,	11	15	5	6	10	7	15	20	13	19	32	49	28	26	13	26
7 ,,	16	12	6	12	11	7	14	19	16	20	33	48	25	26	13	20
8 ,,	15	14	8	11	13	7	10	17	20	17	30	44	25	23	14	22
9 ,,	15	11	6	12	12	6	15	17	17	21	30	46	29	22	14	20

velocity of the wind was 45 miles, or above it, in some part of the British Islands almost continuously for 4½ days. In this Table, and throughout this paper, the factor 8 has been retained, as no systematic change has yet been introduced into the anemometrical records either in this country or abroad. The anemometers used are not all of the pattern known as the large Robinson, but quite irrespective of the difference this would occasion there are wide differences which cannot satisfactorily be explained. For instance, at stations so close together as Holyhead and Liverpool, the average hourly velocities for the 4½ days are respectively 54 miles and 30 miles. On the other hand, it will be seen that the average hourly velocity during the whole period of the gale was identical at Greenwich and Kew, being 23 miles at both observatories.

The absolutely highest hourly velocity in Table I. is 96 miles, recorded at Deerness in the Orkneys at 9 p.m. on the 17th. The hourly velocity at Orkney was 90 miles or above for five consecutive hours, and the observer, Mr. Spence, says "the hurricane commenced exactly at 6 p.m. on the 17th, like the shot of a gun." It will be seen from Table I. that at 5 p.m. the hourly velocity was 14 miles, at 6 p.m. it was 46 miles, and at 7 p.m. it had increased to 81 miles.

There are only five previous instances in 30 years, since 1868, of the wind attaining 80 miles and upwards in the Orkneys; these instances are all given in Table III. (p. 51). The absolutely highest velocity previously observed in Orkneys was 88 miles an hour.

Table II. gives a few of the principal details from Table I. grouped together for the purpose of comparison. From the column showing the maximum velocity it will be seen that the greatest violence of the wind on shore occurred at Orkney, Holyhead, and Fleetwood. The gale was of longest duration at Holyhead, the wind attaining the hourly velocity of 45 miles (force 8 of Beaufort's Notation) or upwards, for 76 hours, while it was 65 miles (force 10) for 31 hours, and for 4 hours it was 85 miles or upwards (force 12).

Table III. gives the dates of severe gales from 1869 to 1893, a period of 25 years, on which the wind velocity was 80 miles an hour and upwards, as registered by the anemometers erected by the Meteorological Office.

The above records in all show 21 gales in which the hourly velocity of the wind has attained 80 miles which have occurred in the British Islands during the last quarter of a century.

The following are notes of squalls recorded by anemometers during the gale on November 18th:—

Deerness.—There is evidence of strong squalls, but owing to the general steepness of the lines it is difficult to separate individual squalls. From 9.55 p.m. to 10.25 p.m. 50 miles were registered = 100 miles per hour. Just before midnight the trace over some minutes gives a rate of considerably over 100 miles per hour.

Fleetwood.—About 10 a.m., for half-an-hour, a rate of nearly 100 miles per hour was attained. Near noon, in severe squalls, a rate of quite 120 miles per hour is shown.

TABLE II.—FORCE OF WIND INDICATED BY VELOCITY ANEMOMETERS, NOVEMBER 16TH, 10 A.M., TO 20TH, 9 P.M.

Station.	Maximum Velocity.			Hours with Velocity			Mean Hourly Velocity for 4¼ days.
	Miles.	Direction.	Date.	45 Miles and above.	65 Miles and above.	85 Miles and above.	
Valencia	60	NNW	18 4 a.m.	31	..	..	33
Dublin	35	N	18 11 a.m. to 1 p.m.	..	..	..	16
Armagh	31	N	18 5 a.m.	..	..	..	15
Orkney	96	N	17 9 p.m.	40	15	7	39
Aberdeen	46	NW b N	18 1 a.m.	2	..	..	24
Glasgow	44	N b E	18 3 a.m.	..	..	..	18
Alnwick Castle	44	SW b S	17 1 p.m.	..	..	..	25
North Shields	69	N	18 9 a.m. to 10 a.m.	16	4	..	33
Fleetwood	87	N	18 10 a.m.	44	12	1	43
Liverpool	49	NW, N	18 8 a.m., 9 a.m., 11 a.m.	6	..	..	30
Holyhead	89	N b W	18 11 a.m.	76	31	4	54
Yarmouth	64	NE b N	20 5 a.m.	31	..	..	33
Greenwich	35	NNW, NNE	18 6 p.m., 8 p.m.; 20 2 p.m.	..	..	..	23
Kew	38	NNW	18 7 p.m.	..	..	..	23
Falmouth	55	NNW	18 10 a.m.	17	..	..	31
Scilly	66	NW, NW b N	18 2 a.m. to 6 a.m.	41	3	..	41

TABLE III.—DATES OF GALES FROM 1869 TO 1893, WITH WIND VELOCITY 80 MILES AN HOUR AND UPWARDS.

Station.	Date and Hour of Maximum Velocity.	Direction of Wind.	Maximum Hourly Velocity.
Sandwick	1869. Feb. 27, 4 a.m.	NW by W	81
Valencia	1871. Jan. 15, 11 p.m.	SSW	81
Holyhead	1872. Nov. 23, 7 p.m.	SSE	80
,,	1877. Feb. 20, 3 a.m.	NW	82
,,	,, ,, 4 a.m.	NW by N	
Sandwick	1877. Nov. 16, 3 a.m.	W	83
Yarmouth	1881. Jan. 18, 11 a.m.	E	80
Valencia	1881. Nov. 21, 10 p.m.	SW	82
Sandwick	1882. Jan. 6, 5 p.m.	W	82
,,	1884. Jan. 20, 9 a.m.	W by S	88
,,	1885. Feb. 21, Midt.	S by E	82
Valencia	1885. Dec. 3, 9 p.m.	S by W	82
Fleetwood	1886. Dec. 9, 9 a.m.	NW by W	80
,,	1887. May 20, 8 a.m.	NW	91
Holyhead	1887. Nov. 1, 11 a.m.	SE	80
Alnwick Castle	1888. Nov. 16, 11 a.m.	SW	80
Fleetwood	1889. Feb. 8, 8 p.m.	NW	86
,,	1889. Oct. 7, 11 a.m.	W by N	85
,,	1890. Oct. 16, 5 p.m.	NW	82
,,	1890. Nov. 7, 9 a.m.	NNW	87
,,	1891. Dec. 11, 1 a.m.	NW	90
Orkney	1893. Nov. 17, 9 p.m.	N	96
Fleetwood	1893. Nov. 18, 10 a.m.	N	87
Holyhead	1893. Nov. 18, 11 a.m.	N by W	89

Holyhead.—The trace is unsatisfactory for observation of squalls, but the required information is supplied by the "bridled" anemometer.

Scilly.—There are no indications of squalls of exceptional strength, but the anemometer here is of smaller size, and the trace is also smaller in width.

Dublin.—Nothing worthy of special remark.

Falmouth.—Nothing remarkable.

Valencia.—Squalls are shown on the trace, but they are not very marked.

Armagh.—Nothing calling for special note.

Aberdeen.—Some well-marked squalls, one at 3.45 a.m. 18th, quite 80 miles per hour.

Kew.—Trace indicates a very squally wind; there are some very distinct squalls shown, but the shortest reliable piece of line does not give more than 55 miles per hour.

The "bridled" anemometer at Holyhead, which is essentially suitable for the registration of gusts, gives several instances of gusts at the rate of 115 miles an hour, using the old factor 8. Gusts of this force were of considerable frequency on the 18th from 6.30 a.m. to 11 a.m., and indeed until 3 p.m. the violence of the gusts was but very little less.

Mr. Dines' "tube" anemometer, which is in work at the Meteorological Office in Victoria Street, Westminster, gave the maximum velocity of the squalls as 73 miles an hour on the 18th between 5 and 6 p.m., the factor 3 again being used.

There were many squalls of considerable interest during the gale, and in some instances they can be traced for a considerable distance over the country. The scope of this paper will not admit of any especial attention being given to these, although it is the squalls in such gales that are of the highest importance, and it is these which probably occasion the largest amount of damage and which render the storm so destructive. One squall which passed over the Metropolis, and was traceable for some distance on its outskirts, took place on the 17th between 5 and 6 p.m., fully 24 hours before the greatest violence of the gale occurred. Mr. Ellis has sent me tracings of the self registering instruments at Greenwich which show this squall to have passed over the Royal Observatory at 5.48 p.m. on the 17th—it is very clearly shown in all the records of the self-registering instruments. At Kew it is equally well marked, and occurred at 5.20 p.m., while Mr. Mawley's anemograms show that it occurred at Berkhamsted at 5 p.m. The same characteristic is shown by two interesting barograms lent by Mr. L. P. Casella, the squall passing over Holborn at about 6 p.m.

It is not possible to give in detail an exact statement of the changes shown by the anemograms, but the following brief summaries may be of interest as supplementing the hourly velocities given in Table I.

Valencia.—There was a decided lull in the wind during the evening of the 16th, and at 7 p.m. the velocity was only 3 miles an hour, the direction at the time being East by south; there was a sudden shift to West-south-west at 9 p.m., after which the wind decidedly increased. The wind afterwards shifted steadily through West to North, where it remained during nearly the whole of the 17th, 18th, and 19th. The maximum force of 60 miles in the hour, which occurred at 4 a.m. on the 18th, was from North-north-west.

Dublin.—The wind hauled steadily from South-east through South and West

to North, where it remained for about 3 days. The strongest wind was from due North.

Armagh.—The wind changed from East through South and West to North, the change being greatest in the early morning hours of the 17th, the direction was East-south-east at 1 a.m. and West at 4 a.m. It remained fairly steady at North for fully 3 days. The maximum force was from North.

Orkney.—The direction was steady at South during the after part of the 16th. On the 17th it drew gradually Easterly, and at 5 p.m. was East by north, the velocity being 7 miles an hour. At 6 p.m. it shifted to North by east, and the velocity had increased to 46 miles an hour; at 7 p.m. it had increased to 81 miles, the direction being North, and it afterwards remained steady at North for nearly three days. The direction from 7 p.m. on the 17th to 4 a.m. on the 19th never varied more than 1 point from North.

Aberdeen.—The direction of wind was steady at South-east till 1 p.m. on the 17th, when it suddenly shifted to West, and during the remainder of the day was unsteady between South-west and North-west. The maximum force was from North-west by north at 1 a.m. on the 18th, and it was afterwards very steady at North for more than 2 days.

Glasgow.—The direction was fairly steady at East till 7 a.m. on the 17th, shifted to South at 9 a.m., West-south-west at 10 a.m., and afterwards through West to North, where it remained steady for nearly 3 days.

Alnwick Castle.—The direction was South-west till 10 a.m. on the 17th, after which it shifted gradually through South and West to North. The maximum force was from South-west by south at 1 p.m. on the 17th.

North Shields.—The wind shifted gradually from South-east through South and West to North, from which latter point the maximum velocity was reached. The direction was steady at North for about 2 days.

Fleetwood.—The wind was fairly steady at South-east throughout the 16th, and on the 17th until 5 a.m., after which it shifted through South and West to North. The maximum velocity was from North at 10 a.m. on the 18th, and the direction remained steady at North throughout the 18th and 19th.

Liverpool.—The direction was South-east throughout the 16th, and was unsteady between South-east, South, and West-north-west on the 17th. It shifted to North-north-west at 1 a.m. on the 18th, and remained within a point or two of North during the next 2 or 3 days. The highest velocity of wind was from North-west.

Holyhead.—The wind was at first South-easterly, and shifted through South and West to North. The direction was steady at North throughout the 18th, 19th, and part of the 20th. The maximum velocity of 89 miles was from North by west at 11 a.m. on the 18th.

Yarmouth.—The direction of the wind was Easterly and South-easterly throughout the 16th, and shifted gradually through South to West by the evening of the 17th, and remained between West and South-west until 6 p.m. on the 18th, after which it shifted suddenly to North, near which point it continued for some time. The maximum velocity was 64 miles an hour from North-east by north at 5 a.m. on the 20th.

Kew.—The direction was chiefly East and South-east during the 16th, and was unsteady between South and West on the 17th. It shifted to North-north-west at mid-day on the 18th, and remained between North-north-west and North-north-east to the close of the 20th. The maximum force was from North-north-west at 7 p.m. on the 18th.

Falmouth.—The direction was between South-east and South-west on the 16th, and between South-west and North-west on the 17th. It shifted to North about mid-day on the 18th, where it remained during the next 2 or 3 days, the direction during this time only varying a point or two on each side of North. The maximum velocity was from North-north-west at 10 a.m. on the 18th.

Scilly.—The wind shifted from South-east through South and West to North, where it remained fairly steady for 2 or 3 days. The maximum velocity occurred at 2 a.m. and 6 a.m., 18th, the respective directions being North-west and North-west by north.

Through the courtesy of the Board of Trade, I have been allowed access to the

official returns which give the casualties to vessels involving either loss of life or saving of life by some extraneous means. The data are accurate and complete, and deal merely with the storm from November 16th to 20th. The total loss of life reported to the Board of Trade within the limits of the *Wreck Chart*, and of four weeks after the date of the storm, on December 15th, was 835 lives from all vessels Foreign and English. The returns are made for our coasts and for a very limited area of the sea adjacent to our coasts, the limitation being that common to the ordinary *Wreck Charts* published annually by the Board of Trade.

The several casualties have been grouped for the respective days of the storm with the following result:—

Nov. 16	Lives Lost	10[1]	Lives Saved	22
,, 17	,,	47	,,	65
,, 18	,,	174	,,	330
,, 19	,,	51	,,	94
,, 20	,,	39	,,	89
Total	,,	321	,,	600

Vessels abandoned, foundered, stranded, &c., in every case involving either loss of life or saving of life by some means other than the vessel experiencing casualty:—

Nov.	16	Number of Vessels	Lost	7[2]
,,	17	,,	,,	22
,,	18	,,	,,	71
,,	19	,,	,,	25
,,	20	,,	,,	15
	Total	,,	,,	140

The Board of Trade returns, from which the above facts are obtained, do not deal with loss of life, &c., in vessels on the open ocean.

In addition to the above, there were on December 16th—four weeks after the storm—21 vessels, many of which are large steamers, posted on the "Overdue" List in the *Liverpool Journal of Commerce*—most of these being probably involved in the storm.

Both the time and position of the casualty are given in the Board of Trade returns, and I made an attempt at producing a Wreck Chart for this particular storm, but in many cases the casualties are too close and too numerous to be pictured on anything like a reasonable sized chart, consequently the losses cannot be shown graphically, and I have considered the lists to be rather too much in detail for the scope and limits of this paper.

There is, however, one special feature. The losses were, for—

Nov. 16	principally on our	west	coasts.
,, 17	,, ,,	north	,,
,, 18	spread over all		,,
,, 19 and 20	chiefly ,,	east	,,

[1] These scarcely belong to 16th.
[2] 2 vessels scarcely belong to 16th.

The National Lifeboat Institution state "that during the recent great gale, lasting from November 17th to 21st inclusive, our lifeboats were launched on service 82 times, and saved 208 lives and 6 vessels. The crews of 22 other life-boats were also assembled in readiness for launching, but their services were not required."

The Secretary of Lloyd's, Col. Hozier, in forwarding a list of casualties, says: "On November 20th we had, I believe, what was our heaviest Loss Book; in that day 144 casualties were posted on it."

For the following statement, which shows the vast destruction of timber in the northern portion of the Kingdom, I am indebted, through the kind courtesy of His Grace the Duke of Sutherland, to Mr. Henry Wright, of the Sutherland Estates Office.

Tongue District of Sutherland. North-west.—The storm began about 3 p.m on the 17th, a point or two West of North; it soon got into true North and remained there for most of the night; later it got round a few points to the Eastward. About 1800 trees were blown down, namely, 819 fir, 417 larch, 147 spruce, 115 birch, 106 beech, the remainder ash, oak, elm, and various. There is much damage to roofs of houses, &c.

Dunrobin District of Sutherland. East side.—Never within living memory had such a storm been experienced on the east coast of the county. The wind was accompanied by heavy rain. It was worst from 8 o'clock till midnight. In the morning (18th) with snow and frost. The estimated number of trees blown down is 52,000, or say, at most, 55,000.

By the aid of the *Pilot Chart of the North Atlantic Ocean* for December, published by the Hydrographic Office of the United States Navy Department, coupled with information obtained from an examination of the logs of vessels which experienced the storm, the storm can be tracked completely across the Atlantic.

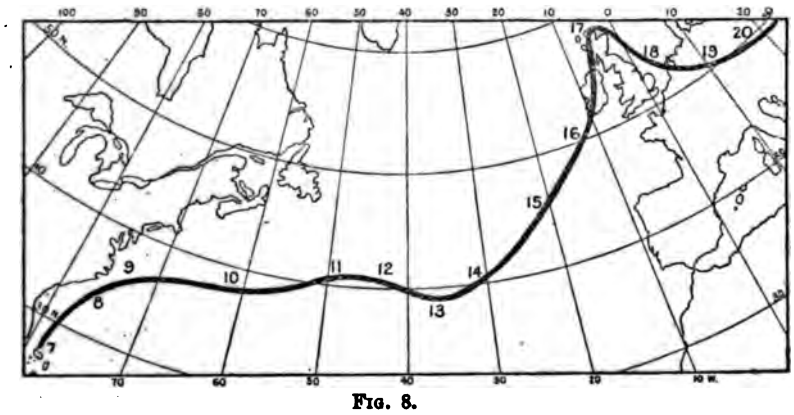


FIG. 8.

The *Pilot Chart* says:—

"On November 7th a depression originated east of the Florida coast near the Bahamas. At the same time an area of high pressure prevailed over the New England and middle Atlantic States. By noon, G. M. T., of the 8th, the depression had moved up the Gulf Stream almost to Cape Hatteras. The area of high pressure in the meantime moved eastward off the New England coast. On the 9th the storm was central just to the northward and close to Cape Hatteras,

Vessels along the coast on the 8th and 9th reported the wind of force 10-11. From Hatteras the storm moved to the northward of east and crossed the Atlantic, as shown graphically on the chart. From reports received, this storm maintained its energy during the entire passage."

I am indebted to the kindness of the Cunard Steamship Company for the log of the ss. *Lucania*, bound from New York to Liverpool. This vessel left New York on November 11th, and from the very time of starting she was under the influence of this storm system, and throughout her passage she experienced North-easterly and Northerly winds, being on the northern side of the storm system until her arrival off the English coasts.

On the 12th, the wind increased to a strong gale with a rapidly falling barometer—ship at noon in lat. 41°28′ N., long. 62°40′ W.

On the 13th a strong North-easterly gale was blowing all day with a high sea, barometer falling slightly—ship at noon in lat. 43°48′ N., long. 54°57′ W.

On the 14th the vessel had gained considerably on the storm system, and during the afternoon she was at her nearest position to the central area of the disturbance, the barometer being as low as 29 ins. A fresh North-easterly gale was experienced during the greater part of the day, the vessel at noon being in lat. 46°6′ N. and long. 46°20′ W.

On the 15th the vessel at noon was in lat. 49°11′ N., long. 38°5′ W., and she again experienced a North-easterly gale throughout the day with a uniformly low barometer.

On the 16th the storm was somewhat outstripping the *Lucania*, travelling more quickly to the eastward, and the vessel experienced a steadily rising barometer, although a fresh to strong North-north-easterly gale was blowing throughout the day. The vessel's position at noon was lat. 50°34′ N., long. 27°0′ W.

On the 17th the vessel was again gaining on the storm, and in consequence she experienced a falling barometer. The wind was between North-north-east and North-north-west, with its force ranging between a moderate and a hard gale. Ship at noon in lat. 51°23′ N., long. 15°30′ W.

On the 18th the vessel experienced a hurricane with terrific squalls—direction steady at North throughout the day. The barometer was rising as the disturbance was again moving Eastwards, and the high barometer in the rear was decidedly asserting itself. Vessel at noon in lat. 52°12′ N., long. 6°2′ W., and before midnight the ship was off the Great Orme's Head.

Owing to the violence of the gale the vessel was 25 hours doing the passage from Roche's Point to the Mersey, while on the outward passage she had covered that distance under 12 hours.

The storm was accompanied by heavy falls of snow, sleet, and rain in many parts of the British Islands, and the gale was exceptionally violent on the French coasts, but the object of the paper is primarily to deal with its effect and influence over the British Islands, and my endeavour has been, as far as possible, to bring the scope of the paper within a limited compass.

In conclusion, I have to thank the Meteorological Council for having so kindly placed the whole of the material in the Meteorological Office at my disposal for the preparation of this paper, and I would acknowledge the great assistance given to me by many Fellows of the Society and others who have so readily communicated their observations.

DISCUSSION.

THE PRESIDENT (Dr. C. Theodore Williams) said that Mr. Harding's communication was full of interesting information. Concerning the reference which had been made to the destruction of trees on the Duke of Sutherland's property, he (Dr. Williams) had heard that on another Scottish estate, that belonging to Lord Strathmore, it was estimated that 100,000 trees, chiefly firs, were blown down. A peculiar feature in the destruction wrought was that the fallen trees were distributed in circular groups.

Mr. F. J. BRODIE said that an interesting feature in the history of the storm was the complete reversal that took place during its progress in the distribution of pressure over Western Europe. At the time the depression first advanced from the Atlantic the barometric readings were highest over Sweden and Denmark, but on November 17th, when the centre moved north-eastwards across Ireland and Scotland, the high pressure system receded eastwards to Russia. It was now evident that in the rear of the disturbance a large anticyclone was advancing over the Atlantic, and on the night of the 17th, when this system reached our western coasts, the storm centre changed its course and moved in a south-south-easterly direction over the North Sea. The alteration in the course of the storm, though quite unexpected at the time, was fully explained in the light of subsequent events, and both in the earlier and later stages of its progress the depression obeyed the well-known law in accordance with which such systems ordinarily move along to the left of the high pressure area existing at the time. Another feature in connection with the movements of this depression was that during its progress down the eastern coast of Great Britain the barometer not only rose in its rear but also in its centre, the minimum readings being half-an-inch higher on the morning of the 18th than they were on the previous morning. The remarkable way in which the wind rose at Deerness was noteworthy, the increase being from 14 miles in one hour to 46 in the next, and then to 81 miles in the third hour. On August 20th, 1889, a similar but rather greater increase of wind force was recorded at Fleetwood, the velocity increasing from 7 miles to 58 miles in consecutive hours.

Mr. H. N. DICKSON said that he first experienced this storm when about 100 miles north-east of the Shetland Isles, on board H.M.S. *Jackal*, and in consequence of the rough weather it became necessary to make for Lerwick Harbour which was reached at 7 a.m. on the 17th. The wind blew strongly from South-south-west all day, but at 7 p.m. it fell to almost a calm. At 7.15 a Northerly gale burst over the harbour with the suddenness of an explosion, and by 8 p.m. it was blowing with hurricane force. The charts showed the position of the centre of the disturbance on the evening of the 17th to have been north-east of Aberdeen, but considering the suddenness with which the Northerly wind burst at Lerwick it seemed probable that the centre was further north than Aberdeen, and nearer Lerwick than the *Pilot Chart* indicated. This storm afforded a good opportunity for study, as the abruptness with which the Northerly gale burst indicated that the centre must have been very well defined. He thought that a consideration of the extent and form of sea disturbance around depressions would be of interest, especially in connection with the storm discussed in Mr. Harding's paper, as he (Mr. Dickson) should have expected a cyclone of such intensity to have raised more sea before it. In the case of what Mr. Harding called the "pilot" disturbance on the 14th, the sea in the neighbourhood of the Shetlands was very considerable, but by the morning of the 15th it was quite calm.

Mr. G. J. SYMONS considered that in the interest of meteorological science it was fortunate that so skilled an observer as Mr. Dickson happened to be within the influence of the storm when it was in the neighbourhood of the Shetlands, as observations from such a source and locality were very valuable. As corroborating the wind records at Deerness, he had been told that at some place in the Orkneys the wind had torn the stack pipe from the wall of a house and blown it through the back door. He should much like to have had the opinion of Mr. W. H. Dines concerning the high velocities registered during this storm. Mr. Dines's father (the late Mr. G. Dines) always refused to believe in the accuracy of these records of great velocities, as from his knowledge of buildings he was

confident that no structure could withstand such pressures as some anemometers indicated.

Mr. W. ELLIS said that meteorologists and sailors were well aware that in stormy or squally weather the wind will not unfrequently change in direction from South-west or South-south-west to North-west, blowing then with increased force and accompanied usually by rain. There will generally be some degree of pressure before the change of direction with increased pressure at the time of change. On November 17th there occurred a very marked case of the kind. Previously to 5.48 p.m. the wind was South-south-west with no very sensible pressure, but at the time mentioned the direction suddenly changed to West-north-west, with an instantaneous increase of pressure to 8 or 9 lbs. on the square foot, accompanied by rain, the remarkable thing being the extreme suddenness with which the pressure sprung up from an insignificant amount to that mentioned. It was a very noteworthy case of the type of weather in question. The barometer had been falling, but at the instant of this change of wind it turned to rise, and continued generally to rise during the remainder of the gale: the change was, as usual, accompanied by sharp fall of temperature. [The various registers were exhibited to the meeting.] He took the opportunity to mention that during the last summer, by an additional gearing applied to the Osler anemometer at Greenwich, a more rapid motion could at pleasure be given to the sheet, causing it to travel with twelve times the ordinary velocity, for use on the occasion of storms. By this spreading out of the register, the variations, both of direction and pressure of the wind, become apparent in a way that is not possible with the contracted register. [A record obtained with the extended scale was shown.] And it is further evident that a yet more extended register was desirable.

Mr. R. H. SCOTT said that it was exceedingly interesting to notice how completely Mr. Dickson's account of the sudden bursting of the Northerly gale at Lerwick corroborated the remark made by Mr. Spence, the observer at Deerness, who had stated that it was "like the shot of a gun." With reference to the question of the possible use of sea disturbance on our coasts as giving warning of the advance of depressions, in 1869 a station was established at St. Anne's Head, Milford Haven. It had previously been maintained by residents in Pembrokeshire that observations of sea disturbance there gave unerring indication of the approach of storms, but during the 24 years that the station has existed the observations of sea disturbance had never afforded warning of any storm there which was not fully indicated by other observations.

Dr. R. BARNES observed that storms of the character described in Mr. Harding's paper served to equalise the character and temperature of the air over wide areas of country. During the gale on December 12th, he had caught some of the rain in clean glasses at his residence at Lyss, in Hampshire, about 15 miles distant from the sea; and had found that the water collected contained a good proportion of sea salt. This ingredient, easily detected, was an indication of other properties carried in the wind from the sea. It was desirable to extend observations of this kind, illustrating the properties of the air, to more inland districts.

Mr. G. J. SYMONS observed that the most remarkable case of the deposit of salt by a strong wind at places inland occurred at Leeds, some years ago, most of the windows facing south-west having a saline incrustation upon them.

Mr. H. HARRIES directed attention to the fact that this severe gale occurred within a few days of the anniversary of the great storm of 1703, a large amount of information about which he had in his possession—information which was not used by De Foe in describing that memorable hurricane. From a study of the data there is some ground for supposing that De Foe's storm occupied four days in crossing the Atlantic, while the one now discussed by Mr. Harding took seven days. Out on the ocean last month's storm area must have been a very extensive one, for the log of the *Lucania* shows the ship to be experiencing the North-easterly gale on the 13th and 14th, when the centre was distant about 900 miles.

ON CHANGES IN THE CHARACTER OF CERTAIN MONTHS.

By ALBERT E. WATSON, B.A., F.R.Met.Soc., F.R.A.S.

[Received September 13th—Read December 20th, 1893.]

It has been said that "a 10 years' average would probably be within 5 per cent. of the true mean of a long series of years."[1] Consequently, we are led to expect that, however much the rainfall and mean temperature of any individual month may differ from year to year, the variations in one direction will, in a few years at the most, be met by variations in the other direction; the result being that in a short series of years, here given as 10, these variations will almost cancel one another, and the mean will remain practically unaltered.

Now, if this rule could be depended on, it is evident that, by considering the character of any particular month in past years, we should have some ground for forming a judgment as to the probable character of that month in future years; *e.g.* if we found that it had been abnormally wet or cold for several years in succession, we should know that, within a very short time, it must necessarily become abnormally dry or hot, in order to restore the balance, or else that the average would be maintained by a longer series of months of an opposite but less extreme character.

But though, in most cases, this is what actually does happen, in some the average is not by any means maintained, so that after a time the nature of a month becomes completely changed, from wet to dry, or from warm to cold, without, apparently, any prospect of a return to its former condition.

To illustrate my meaning, let us take instances from records kept at Croydon, Surrey, as to the reliability of which there can be no manner of doubt.

First, changes in Rainfall.

Taking the records for January in periods of 5 years from 1866 to 1890, we find the following values:—

	Ins.		Ins.		Ins.		Ins.		Ins.
1866	8·68	1871	2·87	1876	1·04	1881	1·11	1886	3·19
1867	3·12	1872	5·54	1877	5·57	1882	1·20	1887	1·63
1868	4·81	1873	4·08	1878	1·14	1883	1·91	1888	·82
1869	2·91	1874	1·15	1879	2·61	1884	2·19	1889	1·16
1870	1·48	1875	3·49	1880	·40	1885	1·94	1890	2·55
Average	3·09		3·43		2·15		1·78		1·87

Hence the rainfall for this month, so far from maintaining its average, has gradually fallen off during these 25 years from a mean of 3·09 ins. for the

[1] Mr. Symons, at a meeting of the Institution of Surveyors, on February 12th, 1877.

first lustrum to a mean of 1·87 in. for the last; or, more striking still, from a mean of 3·26 ins. for the first decade to a mean of 1·80 in. for the last. January has in fact lost nearly 50 per cent. of its rainfall, and instead of being, as it was from 1866 to 1875, by far the wettest month of the year, it has been, from 1881 to 1890, almost, if not quite, the driest.

December is another case in point.

Here the rainfall records, arranged in the same way, are the following:—

	Ins.		Ins.		Ins.		Ins.		Ins.
1866	1·85	1871	1·65	1876	7·43	1881	2·77	1886	4·29
1867	1·61	1872	4·39	1877	1·81	1882	1·96	1887	1·39
1868	4·50	1873	·86	1878	1·46	1883	·57	1888	1·45
1869	3·38	1874	1·80	1879	·92	1884	2·21	1889	1·34
1870	3·03	1875	1·22	1880	3·01	1885	1·18	1890	·78
Average	2·87		1·88		2·93		1·73		1·85

Here the average for the whole series is exactly 2·25 ins., but the average for the last 2 lustra is only 1·79 in., a decrease of 20 per cent. on the whole.

For November the result is quite the reverse, the records being the following:—

	Ins.		Ins.		Ins.		Ins.		Ins.
1866	1·48	1871	·55	1876	2·67	1881	3·54	1886	3·22
1867	·62	1872	3·50	1877	5·05	1882	2·13	1887	4·68
1868	1·15	1873	2·54	1878	3·77	1883	3·56	1888	3·91
1869	2·53	1874	2·59	1879	1·20	1884	1·45	1889	·88
1870	1·89	1875	3·15	1880	2·30	1885	2·71	1890	2·03
Average	1·53		2·47		3·00		2·70		2·94

In this case the mean for the 25 years is just over 2·5 ins.; the mean for the first 10 is 2·00 ins., the mean for the last 15, 2·88 ins. Hence the mean rainfall for this month during the 15 years 1876 to 1890 was not only 14 per cent. greater than the mean for the whole period, 1866 to 1890, but actually 42 per cent. greater than the mean for the ten years 1866 to 1875.

So also in May, the mean for the first 2 lustra, 1866 to 1875, was 1·53 in., but the mean for the last 3 lustra, 1876 to 1890, was 1·96 in. indicating an increase of 28 per cent. on the mean of the first 10 years.

Before leaving this subject, it may be interesting to notice how remarkably deficient in rainfall recent Septembers have been. For this month, the averages for the 4 lustra from 1866 to 1885 were practically the same, viz. 2·79 ins., 2·86 ins., 2·70 ins., and 2·82 ins. respectively, or 2·79 ins. for the whole 20 years, of which not one had a rainfall of less than 1 inch. Now since 1885 the fall has been as follows:—1886, 1·78 in.; 1887, 2·40 ins.; 1888, ·85 in.; 1889, ·98 in.; 1890, ·61 in.; 1891, ·68 in.; 1892, 2·04 ins. These figures give a mean of 1·88 in. both for the fifth lustrum and also for the 7 years, of which 4 in succession had a rainfall, hitherto unrecorded in this

month at Croydon, of less than an inch, while the decrease from the above average is 53 per cent.

The rainfall returns from 1867 to 1876 are taken from Mr. G. Corden's book, *The Meteorology of Croydon;* those from 1877 to 1888 were kindly supplied by Mr. Baldwin Latham, of Addiscombe, and the rest, excepting for 1866, are from my own records at "The Whitgift Grammar School," Croydon. And the points at which they were taken vary very slightly in height above sea-level, and are about a mile apart from one another. For the year 1866 the rainfall is that measured at the Greenwich Observatory.

Secondly, changes in Temperature. Taking the Croydon records of the mean temperature of December from 1876 to 1890 we get the following values :—

	°		°		°
1876	44·2	1881	39·4	1886	36·2
1877	39	1882	39·2	1887	37·6
1878	33·4	1883	39·5	1888	41·1
1879	32	1884	40·6	1889	37·7
1880	43·2	1885	38·4	1890	28·9
Average	38·4		39·4		36·3

The average for the 15 years is 38°·0

Now the mean temperature of December at Greenwich for the 60 years, 1814 to 1873, is given as 39°·9 ;[1] consequently, if we may be allowed to compare the mean temperatures at Croydon with that,—and, considering the nearness of the two places, this seems very reasonable,—the result shows a decrease in mean temperature of 1°·9.

But the mean temperatures of January at Croydon for the same series of years are the following :—

	°		°		°
1876	37·3	1881	31·2	1886	35·3
1877	42	1882	39·9	1887	35·1
1878	40·3	1883	40·6	1888	37·7
1879	32	1884	43·2	1889	37·1
1880	33·4	1885	35·9	1890	43·7
Average	37·7		38·2		37·8

The average for the 15 years is 37°·7.

For Greenwich the mean temperature of January for the above named 60 years is given as 37°·1, so that, instituting the same comparison as before, a rise is here shown of 0°·6. But the remarkable part is, that without comparing Croydon temperatures with Greenwich at all, the average mean temperatures of December and January for the 15 years 1876 to 1890 are almost the same. That is, December has now become as cold as January,

[1] Glaisher, *On the Mean Temperature of Every Day*, 1814 to 1873.

whereas, according to the Greenwich records, there used to be a difference of practically 3°!

October is another month that appears to have become much colder of recent years. The mean temperature of this month is given in the Greenwich records as 50°·1, but the mean for the three lustra 1876 to 1890 at Croydon is only 49°·2, indicating a mean annual decrease of almost a degree. Indeed, a mean temperature of 50° was reached by October only 6 times in these 15 years. October 1892 was also very cold, with a mean temperature of only 46°·1.

These facts seem to show that a 10 years' average is not by any means always maintained, but that on the contrary the character of particular months may change, as time goes on, to a very marked extent. For as we have shown, December has lost 20 per cent. and November gained 14 per cent. on the average rainfall of 25 years, while October is nearly a degree colder than it used to be, and January, which was the wettest and coldest month in the year, has now become almost the driest, and no colder than December, which month has lost nearly 2° in mean temperature. Are these changes local, or have all the stations in the British Isles been similarly affected?

DISCUSSION.

Mr. G. J. SYMONS said that the quotation given at the commencement of the paper did not quite correctly represent the statement he made in an address to the Institution of Surveyors in 1877, which referred to the *annual* rainfall values and not to the values for individual *months*.[1] Monthly averages of various sets of years differed tremendously, but he had said nothing about them.

Mr. C. HARDING said that there were many facts of interest in Mr. Watson's paper, but too much importance had been given to observations which extended over a very short period. It was hardly wise to use sometimes Greenwich observations, sometimes Mr. Latham's observations, and sometimes observations made by the author himself. It would have been more satisfactory if Greenwich records alone had been used throughout, and these were available for a long series of years.

Mr. BALDWIN LATHAM remarked that the earlier observations at Croydon were not very reliable, the method of exposure of the instruments having been unsatisfactory. Possibly some of the differences shown in the paper might be due to that cause.

Mr. H. SOUTHALL said that his experience in connection with Herefordshire observations had taught him that an average of 5 or 10 years would not afford reliable results for monthly values, and even for yearly amounts there were often great divergences between averages deduced from a short term of years. For instance the mean rainfall of one period of 12 years at Ross was 27 ins., while the succeeding 12 years yielded an average of 32 ins.

Mr. A. E. WATSON, in reply, said that Mr. Symons' statement, as quoted in his (Mr. Watson's) paper, had been copied from a book, but he had at the time wondered whether Mr. Symons was referring to annual values merely. He had used the different sets of rainfall observations for Croydon, because he thought as the stations were in such close proximity to each other that the results would be fairly comparable. The temperature observations used were supplied by Mr. Baldwin Latham, of Addiscombe.

1 The words were "the rainfall of a single year may be 33 per cent. either above or below the true average, a two years average may be 16½ per cent. above or below, and so on, the approximation decreasing less rapidly, so that at the end of ten years the average will probably be within 5 per cent. of the true mean of a long series of years."

RAINFALL AND EVAPORATION OBSERVATIONS AT THE BOMBAY WATER WORKS.

By S. TOMLINSON, M.Inst.C.E., F.R.Met.Soc.

(Abridged.)

[Received May 29th.—Read December 20th, 1893.]

Bombay is situated in about 18°58′45″ N. lat. and 72°48′56″ E. long., these figures giving the exact situation of Colaba Observatory. The municipal limits are the Island of Bombay, as it is now called; but great physical changes have in recent times been brought about by engineering works. On the east the Island is separated from the mainland by the Harbour, about 6 miles wide: on the north it is, or rather was, separated from the larger Island of Salsette by a narrow creek, but four embankments now carry the two railways and two roads leading out to the mainland. In the Island of Salsette are situated the works which up to March 1892 supplied the Island of Bombay with water. In 1892 the Tansa Works were opened: these works comprise the Tansa Lake, about 60 miles distant from the Town Hall at Bombay, and a duct bringing in water from Tansa Lake to Bombay. The Tansa Lake is on the mainland of India, and is situated in one of the valleys leading out from the Western Ghats which run on the mainland north and south about 40 miles eastwards from Bombay, and rise opposite to Bombay to over 3,000 feet above sea level.

The climatology of Bombay has been the subject of a large and complete work by Mr. Charles Chambers, F.R.S., Director of the Government Observatory, Colaba, a copy of which work is in the Society's Library.

The accompanying wind chart, reproduced by kind permission from Mr. Baldwin Latham's *Sanitation of Bombay*, and Table I., show the prevailing winds; and as the changes from year to year are comparatively small, the representation is sufficiently accurate for general purposes. The full line represents the frequency of the wind, and the dotted line the proportional velocity.

Roughly speaking, the winds are from the sea (South to North-west) from March to October; and from the land from November to February, and they bring heavy rain in the months of June, July, August, and September, with the probability of some rain in May and October; and there is a possibility of showers in the remaining months.

As no observations on Relative Humidity have been taken at the water works, Table II. is inserted with the kind permission and assistance of Mr. Chambers.

Table III. gives the rainfall registered at Colaba Observatory from 1843 to 1892.

TABLE I.—Direction, and Frequency of Winds at Colaba, Bombay, for the Fifteen Years, 1873–1887.

Direction.	Average Frequency.	Direction.	Average Frequency.
	Days.		Days.
N.....	25·7	SSW	8·2
NNE	18·0	SW.....	14·0
NE	23·5	WSW.....	34·6
ENE	19·6	W	50·5
E.....	8·8	WNW.....	42·9
ESE	8·9	NW	52·2
SE	5·3	NNW	40·1
SSE	6·6		
S.....	6·3	Total	365·2

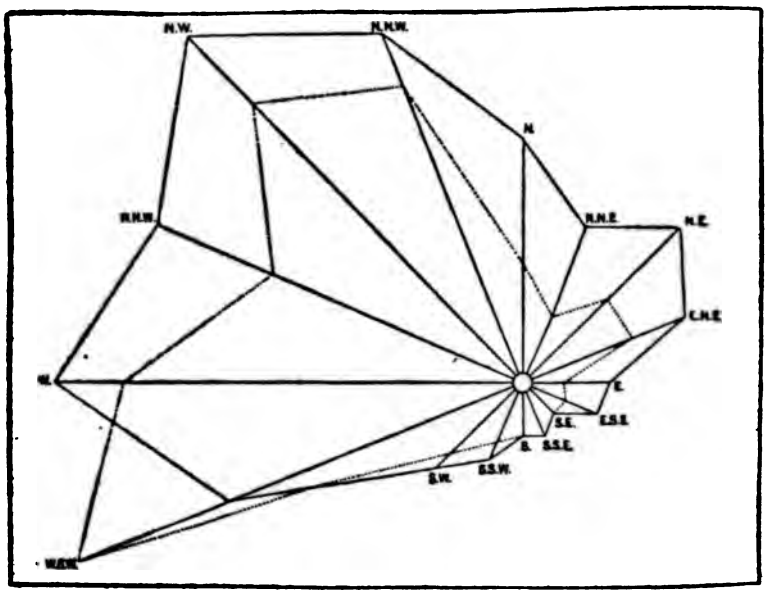


TABLE II.—Average Relative Humidity, 1855–1864, and Temperature of the Air 1873–1892, at Colaba Observatory.

Month.	Relative Humidity.			Temperature.			Month.	Relative Humidity.			Temperature.		
	Min.	Mean.	Max.	Min.	Mean.	Max.		Min	Mean.	Max.	Min.	Mean.	Max.
	%	%	%	°	°	°		%	%	%	°	°	°
January	51	72	89	55·2	73·9	88·6	August ..	77	87	98	71·9	80·0	86·5
February	44	71	89	56·9	74·8	94·8	September	71	86	99	73·1	79·9	88·9
March ..	55	74	88	67·2	78 7	95·4	October ..	62	81	94	70·5	80·7	93·8
April	61	75	86	72·0	81·9	92·2	November	50	72	91	66·1	78 6	93·4
May	65	75	91	74·1	84·2	96·5	December	43	70	89	63·2	75·7	89·4
June	67	83	98	73·2	82·9	91·9							
July	76	88	100	73·7	80·7	88·8	Year ..	43	77·8	100	55·2	79·3	96·5

The Colaba Observatory is situated on the low ridge of land forming the

old Island of Colaba, now joined to the Island of Bombay. It is only 128 feet above Town Hall Datum. This Datum is 100 feet below a certain step on the Town Hall, and this step may be taken as an average rough memory level for the central part of the Island of Bombay, the basalt ridges on the east and west sides of the Island culminating at about 260 feet above Town Hall Datum on the west (Malabar Hill Reservoir), and 240 feet above Town Hall Datum on the east (Cliff over Bhandarwada Reservoir). The mean sea-level is 80·16 feet Town Hall Datum.

TABLE III.—RAINFALL AT COLABA OBSERVATORY FOR THE FIFTY YEARS, 1843–1892.

Years.	Rainfall.	Ratio Average = 100.	Years.	Rainfall.	Ratio Average = 100.	Years.	Rainfall.	Ratio Average = 100.
	Ins.			Ins.			Ins.	
1843	55·24	76	1860	62·15	86	1877	69·89	97
1844	62·71	87	1861	76·91	107	1878	111·93	155
1845	54·12	75	1862	73·63	102	1879	61·40	85
1846	73·93	102	1863	77·68	108	1880	67·94	94
1847	76·00	105	1864	45·57	63	1881	73·04	101
1848	75·86	105	1865	77·85	108	1882	69·23	96
1849	114·89	159	1866	78·44	109	1883	90·18	125
1850	50·25	69	1867	62·30	86	1884	75·44	105
1851	96·07	133	1868	62·12	86	1885	67·91	94
1852	69·27	96	1869	91·66	127	1886	99·74	138
1853	62·60	87	1870	66·21	92	1887	94·95	132
1854	82·14	114	1871	40·58	56	1888	57·82	80
1855	41·18	57	1872	76·48	106	1889	67·84	94
1856	65·92	91	1873	69·70	97	1890	65·18	90
1857	51·27	71	1874	82·18	114	1891	77·18	107
1858	62·45	87	1875	83·09	115	1892	95·12	132
1859	77·16	107	1876	50·04	69			

Average Rainfall for the 50 years, 71·84 ins.

The observations at Colaba are quite independent of the Water Works, and are inserted as a complement to the observations on the Water Works with a view to making a study of the latter more useful and complete.

RAINFALL.

Vehar Lake Observations. The Vehar Lake was built immediately preceding and during the period of the Indian Mutiny (1856-59), and water was first supplied to the City of Bombay in 1860. There is a rainfall record from 1861, results of which are given in Table IV.

There are 4 rain gauges, viz. :—A is situated near the top of the slope of the main embankment, in a completely exposed situation, the funnel of the gauge being 8ft. 4ins. above the pitching of the embankment, and about 7 ft. above the top of the embankment. B is situated on the eastern side of the lake, about 50 feet distant from the top water line; the site is clear, sloping upwards to the south-east. The funnel of the gauge is 8 feet above the ground. C is situated to the north-east of the lake on a clear site, about 40 feet distant from the top water line of the lake. The funnel of

the gauge is about 10 ft. 5 ins. above the ground level. D is situated on the western side of the lake at the top water line. The funnel of the gauge is 10 ft. 1 in. above the ground. The exposure is slightly interfered with at present by trees, and the gauge will be moved a few feet so as to be quite free from the interference of the trees.

TABLE IV.—RAINFALL AT VEHAR LAKE, 1861–92.

Years.	Rainfall.	Years.	Rainfall.	Years.	Rainfall.	Years.	Rainfall.
	Ins.		Ins.		Ins.		Ins.
1861	105·4	1869	91·69	1877	62·71	1885	76·35
1862	96·4	1870	64·97	1878	120·79	1886	104·65
1863	117·1	1871	40·89	1879	76·04	1887	92·86
1864	83·2	1872	65·93	1880	72·42	1888	76·71
1865	88·8	1873	83·72	1881	59·10	1889	85·24
1866	75·0	1874	93·73	1882	54·63	1890	100·04
1867	79·9	1875	74·25	1883	99·54	1891	89·87
1868	70·2	1876	65·68	1884	87·65	1892	129·38

Average Rainfall for 32 years, 83·90 ins.

The water collected in each of the gauges is removed at 6 a.m. by a native watchman, poured into a separate bottle, and carried to the inspector, who measures the quantity in the measuring glass. The 4 quantities are added together and then divided by 4, the quantity entered for the day being therefore the average of 4 gaugings in different parts of the lake, and the yearly total given is the total of such daily averages.[1] So far as the Author has been able to ascertain, the reading at 6 a.m. has always been entered as the reading for the date attached to that day, instead of for the date of the preceding day.

Tulsi Lake Observations. A similar system has been observed at Tulsi Lake, but the works there are more recent, and the record dates only from 1880 (Table V.). Gaugings were taken previous to that, but the record of them appears to have been lost. There are 3 gauges at Tulsi, E, F, G.

E is situated on the western side of the lake, about 50 feet from the water edge and 15 feet above it. Trees interfere with the exposure of the gauge, although not actually overhanging it. The gauge is 5 ft. 6 ins. above the ground. F is situated on the main embankment, and is freely exposed, the funnel is 6 ft. above the surface of the ground. The funnel of the gauge is at about 468 ft. above Town Hall Datum. G is situated near the Bungalow, at an elevation of about 640 ft. above Town Hall Datum. It is near the summit of the hill, which rises rapidly from the water level and is freely exposed to the west and south. The funnel of the gauge is 5 ft. 4 ins. above the ground.

All the gauges, A, B, C, D, E, F, and G, are bottle gauges, with funnels 4¼ ins. diameter. Alongside of each is a Crossley's self-recording gauge, but as the readings of the latter are always less than those of the bottle gauges, they are not taken into the totals.

[1] In the gauges recently established by the Author in the adjoining Pawai Valley the readings of each gauge are separately recorded.

TABLE V.—RAINFALL AT TULSI LAKE 1881–92.

Level of Waste Weir, as raised 1885.... 456·50 ft. above T. H. Datum.
" Lowest Inlet to Tower.....399·36 "

Years.	Rainfall.	Years.	Rainfall.	Years.	Rainfall.	Years.	Rainfall.
	Ins.		Ins.		Ins.		Ins.
1881	84·26	1884	94·84	1887	95·86	1890	116·09
1882	74·22	1885	82·57	1888	89·08	1891	99·47
1883	109·46	1886	108·42	1889	92·91	1892	144·15

Average Rainfall for the 12 years 99·28 ins.

Pawai Lake Observations. The 2 gauges in the Pawai Valley were only established in 1890. They are bottle gauges 5 ins. in diameter. The funnels are placed 1 foot above the level of the ground. The Pawai gauge is near the village of Pawai, on a small island in the lake, at about 198 feet above Town Hall Datum; and the Goper Valley gauge is near the engine house on a clear site, at a level about 168 feet above Town Hall Datum.

Rainfall at Pawai Lake 1890-92.

	Ins.		Ins.		Ins.
1890	93·33	1891	89·20	1892	122·27

Tansa Lake Observations. These observations date from 1886. The rain gauge is fixed on the ridge of the hill into which the southern end of the dam is tied. The site is clear, declining to north and south. The funnel of the gauge is 2 ft. 11ins. above the level of the ground; it is protected by plank fence, at 3 ft. distance, 2 ft. in height. The gauge is 5 ins. diameter. The level of the funnel above Town Hall Datum is 428·76 ft.

Rainfall at Tansa Lake 1890-92.

	Ins.		Ins.		Ins.
1887	106·49	1889	91·44	1891	80·66
1888	86·81	1890	99·47	1892	109·40

EVAPORATION.

The Malabar Hill Reservoir is roofed over. The evaporation taking place from a wooden box, 10 ins. square, 18 ins. deep, placed under the roof, but not in the water, was in May 1888 one-twelfth of an inch per day.

At Bhandarwada Reservoir the only observations made up to the present were in May and June 1891, in connection with the testing of the uncovered filters for leakage after repairs. Filter No. 6 is immediately adjoining the vertical cliff on the east, which was formed by blasting away the rock so that the Reservoir works should be upon the uniform level of 190 ft. above T.H.D. top water level. The boxes employed were of tinned plate, as used for kerosine oil, and each was tested for water tightness before being put into the filter basin; one wooden box was used in one filter alongside the tinned box. The details of the observations (in this case made by the Author) are given in Table VI.

The Cushions Nos. 1 and 2, from which it will be observed the evaporation

was less than from any of the boxes, are not freely exposed to the north, being 8 ft. 6 ins. below the coping of the wall and thereby shielded from the prevailing wind at the time the observations were taken. As remarked above, No. 6 is probably greater on account of the proximity of heated rock.

The results are important only as indicating what is the maximum evaporation from comparatively small sheets of water during the hottest part of the year; and as illustrating the difficulty of obtaining reliable results from small boxes accessible to birds. The filters are visited by considerable numbers, and the boxes attract special attention. It will be noticed that the loss from the basins 1, 2, and 4 (and 5 for part of the period) was less than that from the evaporating boxes, even supposing the basins to be absolutely watertight.

TABLE VI.—EVAPORATION FROM THE BHANDARWADA FILTERS. (EACH FILTER IS 200 FEET LONG BY 80 FEET BROAD.)

Period.	Filter.	Evaporation.
	Ins.	Ins.
Total Evaporation for May 1891, based on observations from		
Filter No. 1, 5th to 16th	10·54	13·21
Filter No. 2, 11th to 16th	11·10	13·83
„ No. 4, 22nd to 1st June	10·94	12·78 wood. 13·67 tin.
Evaporation for June—		
Cushion Filter No. 1, 1st to 17th	7·73	..
„ No. 2 „ „	8·20	..
Filter No. 3 „ „	13·32	..
„ No. 4 „ „	10·74	9·00 wood.
„ No. 5 „ „	11·46	12·41
„ No. 6 „ „	14·13	12·47

Mint Tank. In September and October 1887 some observations were made of the loss from the tank attached to the Mint in Bombay, which is 258 ft. diameter and fully exposed. The experiments were not conclusive, but, so far as they can be used, indicate an evaporation of over one quarter of an inch per day. The Author does not consider that the observations should be seriously considered, as the temperature of the water in this tank was above that of the air, the water being used for condensing purposes. A further objection is that the water level at the time of the observations was about 10 feet below the coping of the wall, and the air circulation was thereby interfered with, as well as the exposure to the sun.

Vehar Lake. Top water level 268·5 ft. above T.H.D.

The observations of evaporation were commenced at Vehar on November 8th, 1890. The box used is of wood, painted; 10 ins. square, 18 ins. deep. At the commencement of each month the water is filled up to a depth of 14 ins., and the observations are made daily. Two boxes are now maintained. In one the water level is started at the beginning of the month 1½ ins. above the water in the lake; and in the other 1½ ins. below. This plan is adopted as a check against leakage. The boxes are placed at a short distance from the shore, where they can be stayed, and are believed to be free of gain or loss from wave splashing.

Tulsi Lake. Top water level 456·50 ft. above T.H.D.

The observations were commenced on January 1st, 1891. During 1891,

TABLE VII.—MONTHLY TOTALS OF EVAPORATION AT DIFFERENT PLACES, IN 1890, 1891, 1892 AND 1893.

Month.	Vehar Lake.								Tulsi Lake.					Tansa Lake. Water Area about 3,000 acres.			Pawai Lake. Water Area about 300 acres.									
	1890.		1891.		1892.		1893.		1891.	1892.		1893.		Gross Fall of Surface of Water in the Lake: no inflow.			1890.	Small Inflow percolation from Vehar.			1891.		1892.		1893.	
	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 1.	No. 2.	No. 1.	No. 2.	1890.	1891.	1892.	Gross Fall of Surface of Water in the Lake.	1891.	1892.	1893.	No. 1.	No. 2.	No. 1.	No. 2.	No. 1.	No. 2.
	Ins.		Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.		Ins.	Ins.	Ins.	Ins.
Jan. ..	..	No. 2 box not fixed.	5·50	..	5·00	5·00	3·87	3·87	6·5	3·87	..	3·87	3·87	..	5·28	4·44	..	2·4[8]	6·3	4·8	5·25	..	3·87	3·87	3·87	3·87
Feb. ..	..		5·25	5·25	4·37	4·37	..	..	5·5	4·75	..	..	..	7·56	5·64	8·88	..	..	..	..	3·25	..	3·62	3·62	..	..
March	..		6·00	5·37	6·5	6·5	..	..	7·75	4·25 ?	..	..	..	6·48	7·56		..	..	..	..	..	..	6·00	6·00	..	..
April ..	..		5·25	5·37	7·5	7·5	..	..	7·87	4·50 ?	..	..	..	6·84	7·68		..	..	..	..	..	..	7·50	7·50	..	..
May	..		7·00	6·75	7·75	7·75	..	..	8·25	3·87 ?	..	..	..	9·72	9·36		..	..	..	..	..	..	7·75	..	..	..
June ..	..		..	..	..	..	..	..	5·25[5]	..	..	..	..	..	4·92[7]		..	..	..	..	..	..	..	..	..	..
July ..	..		..	..	..	..	..	..	..	..	..	..	..	..	..		..	..	..	..	..	..	..	..	..	..
Aug. .	..		..	..	..	..	..	..	..	..	..	..	..	..	..		..	..	..	..	..	..	..	..	..	..
Sept. ..	..		..	..	..	..	..	..	..	..	..	..	..	..	..		..	..	..	..	..	..	..	..	..	..
Oct. ..	..		4·17[3]	4·05[4]	..	..	..	..	5·42[6]	..	..	..	..	5·86	4·68		..	8·4[9]	..	..	..	..	..	..	..	..
Nov. ..	2·75[1]		4·37	4·00	4·5	4·5	..	..	4·25	3·75	3·75	..	..	5·04	6·24		..	9·0[9]	4·5	4·75	4·75	..	3·75	3·75	..	..
Dec. ..	4·25[2]		5·62	5·50	3·87	3·87	..	..	3·87	3·87	3·87	..	..	3·32	5·16		4·80	6·0	5·1	4·62	4·62	..	3·87	3·87	..	..

[1] 8th to 30th. [2] Evap. 3·75, Rain ·50 = 4·25. [3] Evap. 3·62, Rain ·55 = 4·17. [4] Evap. 3·50, Rain ·55 = 4·05. [5] 1st to 20th. [6] Evap. 5·00, Rain ·42 = 5·42. [7] Rain. [8] 1st to 18th. [9] Water flows over waste weir by wind

and up to November 1892, there was only one box in which the water was kept about 1¼ ins. above that of the water in the lake. The box is similar to those at Vehar. In November 1892 the position of the boxes was altered, as the former position was exposed and splashing took place. The readings, which by this wind action have been rendered rather doubtful, are indicated by a ?

Powai Lake. Top water level 190 ft. above T.H.D.

The observations were commenced on January 1st, 1891, but as the lake was run off later in the year, the record is broken.

Direct observations of the evaporation from the Vehar and Tulsi lakes are not practicable, because the quantity drawn off and the area of the water surface at different levels are not known with sufficient accuracy to place calculated results beyond doubt.

Tansa Lake. No direct observations of evaporation have been made, but during construction, water was stored to increasing depths after each season's work, and the levels of the water on the 1st of each month in 1890, 1891, and up to 1892, are given in Table VII. (p. 69).

Evaporation during the Monsoon. No opportunity has occurred for determining the evaporation from large areas of water during the Monsoon. Such figures, however, as have been obtained tend to show that evaporation in the Monsoon proceeds at a much greater rate than is generally supposed. The rain gauges, being at an elevation of several feet above the ground, probably register less than if placed on the water level, the same as the evaporation boxes. The figures show that the evaporation boxes have almost invariably indicated evaporation even on days when rain fell. Further experience may help to fix the quantity. The figures confirm those given in Beardmore's *Hydrology*; and probably ordinary evaporation boxes would be comparatively free from error due to birds drinking during the Monsoon, because they may drink almost anywhere and at any time.

TABLE VIII. APPROXIMATE MONTHLY AVERAGE EVAPORATION IN INCHES WHICH MIGHT BE EXPECTED FROM SURFACES OF WATER IN THE NEIGHBOURHOOD OF BOMBAY.

Month.	From a small surface, say 1 square foot.	From a Reservoir of say 10,000 square feet.	From a Lake of 300 to 3,000 acres.
	Ins.	Ins.	Ins.
January	7·5	6·5	5·0
February	7·0	6·0	5·5
March	9·0	8·0	6·0
April	10·0	8·5	7·5
May	12·0	10·0	8·0
June	5·0	5·0	5·0
July	3·5	3·5	3·0
August	4·0	4·0	4·0
September	4·5	4·5	4·0
October	7·0	6·0	5·0
November	8·0	7·0	4·5
December	8·0	7·0	5·0
Year	85·5	76·0	62·5

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

November 15th, 1893.

Ordinary Meeting.

C. THEODORE WILLIAMS, M.A., M.D., President, in the Chair.

ARCHIBALD WILSON ANDERSON, Chief Weather Bureau, Brisbane;
SHELFORD BIDWELL, M.A., LL.B., F.R.S., Riverstone Lodge, Southfields, S.W.;
RICHARD BAXTER BOOTH, LD.S., 9 Market Square, Crewe;
JOHN MITCHELL BRUCE, M.D., F.R.C.P., 70 Harley Street, W;
ROBERT HENRYSON CAIRD, Southbroom House, Devizes;
JOHN HENRY CHALONER CHUTE, Ballinasloe, Co. Galway;
FRANCIS DRUCE, Upper Gatton, Merstham;
REV. FRANCIS HARVIE, FOWLER, M.A., Barnwood, Gloucester;
EDWARD LEADER HANNA, Rockhampton, Queensland;
GEORGE HENRY HILL, M.Inst.C.E., 3 Victoria Street, S.W.;
WALTER CUNNINGHAM HUME, Government Lands Office, Brisbane;
CHARLES JOHN LEESON, Croydon, North Queensland;
JOHN MICHAEL NICHOLLS, L.R.C.P., St. Ives, Cornwall;
HENRY FRANKLIN PARSONS, M.D., 4 Park Hill Rise, Croydon;
GEORGE VICTOR PEREZ, M.B., M.R.C.S., Puerto Orotava, Teneriffe;
JOHN BARWISE SCURFIELD, Mitchell, Queensland;
SAMUEL SINNAMON, Junction Creek, North Queensland;
FRANCIS DRUMMOND GREVILLE STANLEY, F.R.I.B.A., Brisbane;
DERWENT HUTTON RYDER WALDRON, M.B., C.M., Accra, Gold Coast;
JOHN GEORGE WALLER, 118 Powis Street, Woolwich; and
JAMES GEORGE WOOD, M.A., LL.B., F.G.S., 115, Sutherland Avenue, W.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read:—

"THE GREAT DROUGHT OF 1893 AND ITS ATTENDANT METEOROLOGICAL PHENOMENA." By FREDERICK J. BRODIE, F.R.Met.Soc. (p. 1.)

"THUNDER AND HAILSTORMS OVER ENGLAND AND THE SOUTH OF SCOTLAND, JULY 8th, 1893. By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 31.)

December 20th, 1893.

Ordinary Meeting.

C. THEODORE WILLIAMS, M.A., M.D., President, in the Chair.

ROBERT ELLIS LORD, M.D., B.Sc., M.R.C.S., Abergele Road, Colwyn Bay; and
Capt. GEORGE P. SCOTT, 41 Hartington Road, Liverpool,
were balloted for and duly elected Fellows of the Society.

Mr. J. S. HARDING and Mr. A. E. WATSON were appointed Auditors of the Society's Accounts.

The following Papers were read:—

"THE GREAT STORM OF NOVEMBER 16TH-20TH, 1893." By CHARLES HARDING, F.R.Met.Soc. (p. 43.)

"ON CHANGES IN THE CHARACTER OF CERTAIN MONTHS." By A. E. WATSON, B.A., F.R.Met.Soc. (p. 59.)

"RAINFALL AND EVAPORATION OBSERVATIONS AT THE BOMBAY WATERWORKS." By S. TOMLINSON, M.Inst.C.E., F.R.Met.Soc. (p. 68.)

CORRESPONDENCE AND NOTES.

Comparison of the Readings of two sets of Maximum and Minimum Thermometers in a Stevenson Screen.—Mr. J. Lovel, of Driffield, writes:—"Having had in my possession since 1890 two pairs of maximum and minimum thermometers by different makers, mounted in the same screen, a new pattern Stevenson, I thought it might be useful if I compared their readings for a period when all the instruments were read and set at 9 a.m., the Climatological plan, and also when one pair was read and set at 9 a.m. and the other read and set at 9 p.m., the Second Order plan. This has now been done during the past year 1893, and the results are interesting.

From May 1890 to the end of December 1892, both pairs of thermometers were read and set at 9 a.m., and although the maximum is a Standard instrument by Casella, with Kew certificate, I found it necessary to apply a correction of 1°·0 to bring it into accordance with the other maximum by Negretti and Zambra. When this was done, the instruments were practically identical in their readings with an average difference per month of only 0°·003 in 1892.

The minimum thermometer readings were also fairly regular, an average difference of only 0°·006 per month was obtained, although one of them is regarded as an extra sensitive instrument, being a Casella's Link pattern (no index errors).

When the instruments had been sufficiently brought into agreement with each other, at the beginning of 1893, one pair was read and set as usual at 9 a.m. and the other pair read and set at 9 p.m. As a final result of the experiment in the twelve months of 1893, it was found that the maximum when read at 9 p.m. averaged 0°·194 per month lower than when read and set at 9 a.m.; and that the minimum also averaged 0°·309 lower. A somewhat similar result is shown, though in a smaller degree, in a paper by Mr. Ellis in the *Quarterly Journal*, Vol. XVI. p. 213; the Second Order average maximum there given being 0°·06 below the Climatological average maximum, and the Second Order average minimum 0°·08 below the Climatological average minimum on the three and four years' averages respectively. Taking the individual years, the differences are —0°·08, —0°·04 and —0°·10 for the maximum temperature, and —0°·26, +0°·06 and —0°·11 for the minimum in the years 1886, 1887, and 1888, showing on the whole a decided tendency of the Climatological method of recording temperature to give a slightly higher reading than the Second Order system.

Perhaps a further series of observations might modify the results, but the indications, so far as present observations go, clearly point to a slight lowering of the mean annual temperature from stations of the Second Order when compared with those on the Climatological plan."

Hailstorm in Lincolnshire, August 22nd, 1893.—On this date a remarkable storm of rain and ice occurred between 4 and 4.30 p.m. over a small district on the Lincolnshire Wolds bounded on the south by Fotherby, South Elkington, Welton, Biscathorpe, and Hainton, and on the north by Ludford, Kelstern, North Ormsby, and Utterby. In this space of about 10 miles east to west, and 2 to 3 miles north to south, much damage was done to corn crops, gardens, and glass. A party driving barely escaped an upset, as the horse was paralysed by the force of the storm. Their dog was killed on the road, and many chickens were beaten to death in the farmyards. At Hainton Hall gardens the ice was gathered up

by the barrow load, pieces in some parts remaining unmelted until next morning.

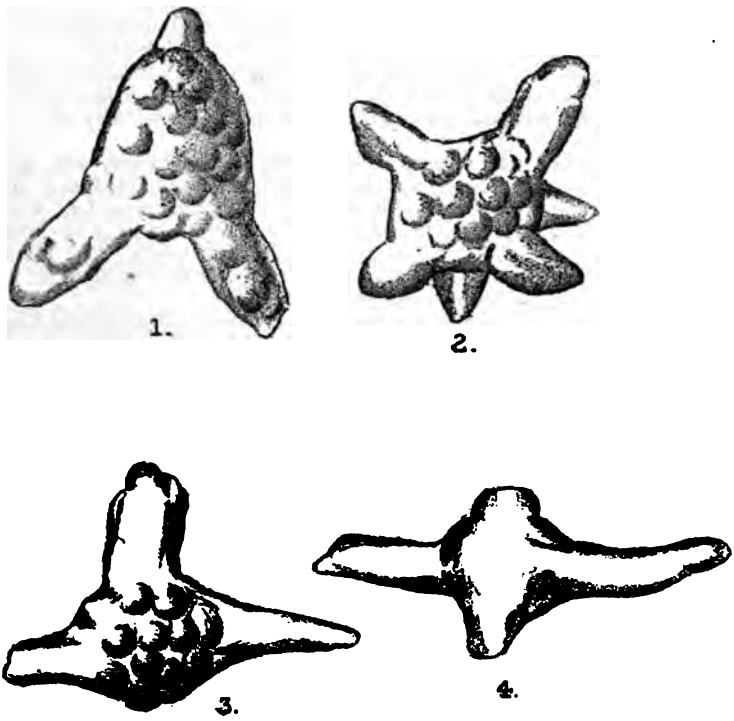
The Rev. J. M. Coates made the accompanying sketches of some of the stones which fell at Welton-le-Wold at 4.30 p.m.

Fig. 1 weighed 90 grains 15 minutes after it fell.

Fig. 2 was drawn 42 minutes after it fell.

Fig. 4 measured $2\frac{3}{16}$ ins. in length 50 minutes after it fell.

In Figs. 1, 3, and 4 the projections were all roughly in one plane. In fig. 2 the projections extended from all sides.



Hail Stones (actual size) which fell at Welton-le-Wold, Lincolnshire, August 22nd, 1893.

The largest stones remaining on the grass lawn were not quite melted away after two hours. The temperature of the air was probably about 70° at 4.30 p.m. There was no appearance of crystalline structure in any of the hailstones examined, but rather of aggregation of globular stones of small size in the projections as well as in the globular nuclei.

Thunderstorm Phenomena.—Mr. H. Bedford, of Newton Abbot, Devon, writes under date of December 12th, 1893: "We were visited this morning by a curious thunderstorm. The first thing I heard was a *hissing* noise, then a loud report like a cannon. This was repeated three times, finishing off with a long loud report. The whole phenomena appeared to be one obstructed clap of thunder. It was followed by great stillness for about five minutes, then by a most vivid flash of lightning and ordinary thunder. There was hail, rain, and gusts of wind. This morning is the most wretched looking I ever witnessed. I noticed on Thursday last, I think, a report in one of our local papers that a ball resembling a small moon had been seen in the north direction, descending perpendicularly, and exploding with falling sparks, and someone had also seen a mysterious light the same night in the south."

Heavy Rain at Nice.—Mrs. Sturge writes that she and Dr. Sturge arrived at

Nice on September 30th, 1893, in such a deluge of rain as has not been known for years. It was calculated that at least 8 ins. fell in the 24 hours ending 9.30 a.m. on October 1st; 7½ ins. were measured, and a considerable quantity had overflowed the rain gauge. *Nice Médical* gives for September 30th 194·4mm.=7·655 ins. from the Avenue des Fleurs (St. Philippe). On the same day the observatoire gave 88·4 mm., the Ecole Normale 157 mm., and the Station Agronomique 178·2 mm. [ED.]

Meteorological Nomenclature.—Prof. Cleveland Abbe, in the *Monthly Weather Review* for August 1893, remarks on the great diversity in the usage of meteorological terms by the daily press and meteorological observers, and states that in the *Weather Review* the following usages will be adhered to:—

The terms "high" and "low" will refer to areas in which barometric pressure is decidedly above or below that of the surrounding country, without reference to any normal values and without implying any specific peculiarity as to winds or weather.

The word "storm" will refer to a disturbance of the ordinary average conditions or to unusual phenomena, and unless specifically qualified may include any or all meteorological disturbances, such as wind, rain, snow, hail, thunder, etc. This word may be qualified by some peculiarity, *i.e.* sandstorm or duststorm (such as the "simoon"), hot wind (such as the "khamsin," or "fōhn," or "chinook"), cold windstorm (such as the "norther" and the "pamperos"), cold rainstorm and snowstorm (such as the "blizzard").

A "hurricane" or "typhoon" is a large stormy area, often several hundred miles in diameter, within which violent winds circulate around a centre. The centre of a hurricane or typhoon is a comparatively calm region, where even the clouds break away and the rain ceases, whereas the centre of a thunderstorm is the region of greatest intensity of wind, rain, or lightning.

A "tornado" is a very much smaller region, usually less than two miles in diameter, within which even more violent wind prevails. In the typical tornado these violent winds circulate about a central axis, rapidly ascending at the same time and forming a funnel-shaped cloud whose base is at the average cloud level; but many destructive winds have been classed as tornadoes which are not circulating about such a funnel-shaped cloud or vertical axis, but which are either blowing straight ahead on the earth's surface, as in the "Derecho" or straight line wind, or which have a quasi-rotation around a horizontal axis, as in the blast that accompanies the front of a "norther" or the gust in front of the heavy rain of a thunderstorm. We shall endeavour, as far as possible, to separate the true tornado, which is rare, from the numerous destructive winds, squalls, and gusts which are popularly called tornadoes, hurricanes, cyclones, tourbillons, and other high sounding names.

The term "whirlwind" is applied to any revolving mass of air, and includes at one extreme the hurricane, and at the other extreme the dust whirl of our street corners.

A "cyclone" is a mass of air circulating around a centre; the lower portion of the air near the earth's surface has a vorticose movement in towards a centre, while the upper layers have a movement out from a centre; the line joining the upper and lower centres is the axis of the cyclone; the direction of rotation is the same in both upper and lower layers. In the Northern Hemisphere this rotation is said to be in a negative direction, or opposite to the diurnal motion of the sun in azimuth, and opposite to the movement of the hands of a watch lying with its face uppermost.

An "anticyclone" is a mass of air also circulating around a centre, but the lower layer of air has a movement out from a centre and the direction of rotation is opposite to that of a cyclone, being positive in the Northern Hemisphere.

The terms "cyclone" and "anticyclone" do not describe phenomena that can be observed by one observer or at a single station, they should, therefore, not be used in the description of local phenomena; they represent generalisations based upon the charting and study of winds and clouds observed at many stations, and should only be used when the nature of the rotation of the winds has been clearly demonstrated or can be safely inferred.

The terms "cyclonic winds," "cyclonic system," and "cyclonic rotation" are equivalent to "cyclone." The outer portion of a cyclone generally has feeble winds and fair weather; therefore a hurricane, tornado, or whirlwind is only a small part of a cyclone.

Rainfall of India.—This is the title of a thick folio volume issued by the Meteorological Department of the Government of India. Previous to the year 1890 there were large differences in the hour of measuring rainfall, in the form of rain gauge used, and in the methods of registering rainfall in the different provinces of India. The want of uniformity in the methods of registering rainfall was due to the fact that the establishment of rain gauge stations and the collection of the data were commenced many years ago by the Revenue Departments of the various local Governments. Each Government naturally established the system which was thought at the time best suited to local conditions and requirements. The disadvantages became more and more evident from year to year, and at length the Government of India in 1890, after a careful consideration of the question, ordered the following changes to be made in order to secure the uniformity of system that appeared to be desirable :—

1. That a common hour for rainfall registration, viz. 8 a.m., and a common rainfall week, ending on Saturday 8 a.m., should be adopted throughout the whole of India.
2. That all rain gauges should be systematically inspected, and that copies of all inspection reports by local officers should be sent to the Meteorological Reporter to the Government of India for his information, and in order that he may make, when desirable, suggestions for the improvement of any rain gauge station at which the arrangements are not satisfactory.
3. That 5 inch Symons' rain gauges, tested by the Meteorological Department, should be the only description of gauge used.
4. That monthly returns of rainfall should be published by each local Government, of which copies shall be bound together and issued as an annual volume by the Imperial Meteorological Department.
5. That the Imperial Meteorological Department should adopt a fixed division of the year into four periods, corresponding with the periods of general rainfall throughout the year in India, for purposes of comparison.
6. That for the purpose of calculating the number of rainy days a fall of one tenth of an inch and upwards should be taken to denote a rainy day.

These changes came into operation January 1st, 1891, and the volumes for 1891 and 1892 have now been published.

Daily Weather Charts of the Indian Monsoon Area.—The Government of India has sanctioned the publication for a period of two years of *Daily Weather Reports and Charts of the Indian Monsoon Area* with a view to elucidate, if possible, the relations between the larger meteorological changes in the Indian land area and the adjacent sea areas, and more especially the conditions preceding the generation of cyclonic storms and the conditions determining the larger advances of South-west Monsoon winds in the Indian seas, and the variations in the strength of the Monsoon currents so far as they are dependent upon conditions in the sea areas.

All ships that enter the ports of Bombay and Calcutta are visited by clerks of the Bombay and Calcutta Meteorological Offices in order to make extracts of the meteorological information in the logs of the vessels, when permitted by the ship's masters. They also, when allowed, make comparisons of the ships' barometers with portable secondary standards. This information is regularly collected and tabulated, and is the basis of the data given in the Daily Weather Reports and Charts of the Indian Monsoon Area which have been prepared and issued by the Simla Meteorological Office since January 1st, 1893.

These daily weather reports may to some extent be considered as supplementary to the India *Daily Weather Reports* published by that office.

Climate of Mashonaland.—Mr. R. M. W. Shaw, a member of the Archæological Exploration Party of Central Africa, in a paper, read before the Philosophical Society of Glasgow, on the "Geography of Mashonaland," says:—The meteorology of the high plateau is interesting and extraordinary. Over the dry Kalahari Desert we experienced many electric storms; in fact almost every evening there were brilliant displays of summer lightning. At Zimbabwe I took continuous readings of the dry and wet bulb thermometers and of the barometer for the two months of June and July, and these give us a fair idea of the climate at that time. During the first week we had South-easterly winds, a high barometer, and

rain and mists. The wind then fell, and the barometer with it, and we had three weeks of fine calm weather. The barometer reached its minimum on June 27th, and at the same time the difference of the readings of the dry and wet bulb thermometers was at its maximum—that is to say, the air was driest with a low barometer. The sky was then clear with light North winds, which were evidently local in origin, and the temperature at night fell below freezing point, so that in the morning we saw a light deposit of hoar frost. Immediately after this the barometer began to rise, there were light South-easterly winds, the atmosphere became moister, and on July 4th the South-easterly winds had increased considerably in strength, and some rain fell. From this time until August 2nd the barometer slowly rose and fell, its range being limited to three-tenths of an inch, and whenever the South-easterly winds blew at all strongly the barometer rose, and we had mist and rain.

At first sight it seems surprising that we should have windy wet weather with a high barometer, but we must remember that the only winds which can bring rain to Zimbabwe, at least in winter, are the South-easterly winds, and these, like all winds blowing towards the Equator, increase the atmospheric pressure. Zimbabwe is situated on the edge of a plateau about 3,400 feet above sea-level. The country breaks down gradually towards the south and east, and more rapidly towards the west; while towards the north it rises gently until, after about 100 miles, it attains an altitude of 5,000 feet. The West winds, if they do blow, have to traverse the continent and high country, about the sources of the Limpopo, before they reach Zimbabwe, and the Northerly winds would tend to increase in temperature after falling from the high country towards the north; so that neither of these winds will deposit moisture at Zimbabwe under ordinary circumstances. The predominant winds in this latitude are the South-easterly Trades, and they, carrying their moisture from the Indian Ocean, are forced to rise as they pass over this country, and they consequently expand and are lowered in temperature, and so deposit much of their moisture on this edge of the high plateau. A similar winter climate seems to prevail in most parts of Mashonaland, the edges of the plateau receiving most of the moisture. Manica is situated much nearer the sea than Zimbabwe, and the country there falls much more rapidly towards the east, and consequently the rainfall there is heavier. Fort Salisbury is better situated for a dry winter, for it is in the middle of a high plateau, and the South-easterly winds will have parted with most of their surplus moisture for that altitude before they reach it.

Gale in the Bahamas, Oct. 9-11, 1893.—Mr. A. Shea, the Governor, Nassau, in a despatch to the Colonial Office, states:—These Islands have been visited by a severe storm, and though the damage is less than had been apprehended, a considerable amount will be required to repair the injury to wharves and other public property.

The barometer showed signs of disturbance on Monday, October 9th, the wind having backed from North-east to North, increasing to force 7. On Tuesday the wind was North-north-west, force 8, barometer 29·86 ins. at 4 p.m. The glass then fell gradually until the afternoon of Wednesday the 11th, reaching its lowest point, 29·46 ins., at 6 p.m., when the force of the wind was 8 to 10. The wind had then veered to West-north-west with heavy squalls until it settled to South-west. During the night of Wednesday the glass rose gradually, and the following morning the weather cleared up.

The sea is said to have been the heaviest ever known here, and the wharves and other waterside private property are a good deal injured. The dwelling of the Assistant Lighthouse Keeper on Hog Island at the entrance to this harbour was washed into the sea, the inmates having but a few minutes before quitted it for shelter in the keeper's house. The latter seemed in such imminent danger that a crew from the Imperial Lighthouse tender *Richmond* manned a boat at considerable risk, and effected the rescue of both families. Mr. Stephen Albert Dillet, the second officer, was in charge of the boat, and this is the second occasion since my arrival here on which this officer performed gallant and highly meritorious service of the same character.

The accounts from the out islands that have so far come to hand report more or less damage from the heavy sea, but nothing serious from the wind. I have not yet heard from Abaco, where I fear the gale was most felt, as was the case in the August storm (see *Quarterly Journal*, Vol. XIX. p. 260).

Climate of New Zealand.—Sir James Hector, in the *New Zealand Official Year Book* for 1893, gives an account of the climate of the Colony. He states that the climate resembles that of Great Britain, but is more equable, the extremes of daily temperature varying throughout the year by an average of 20° only, whilst London is 7° colder than the North, and 4° colder than the Middle, Island of New Zealand. The mean annual temperature of the North Island is 57°, and of the Middle Island 52°; that of London and New York being 51°. The mean annual temperature of the different seasons for the whole colony is: spring, 55°; summer, 63°; autumn, 57°; and winter, 48°. The climate on the west coast is more equable than on the east, the difference between the average summer and winter temperatures in the north-west portion of the North Island being nearly 4° less than in the South-east, while as between the corresponding portions of the South Island the differences vary by some 7°. This is due to the action of the equatorial winds, which impinge on the west coast. The extent of their influence can be better appreciated by comparing the annual fluctuations of temperature on the opposite sea-boards of the Middle Island. At Christchurch on the east, the range is greater by 7° than at Hokitika on the west.

The northern part of New Zealand is within the influence of the subtropical winter rainfall, the probability of rainfall in winter in that part of the colony being twice as large as in summer. In the south, however, the rainfall, though irregular, is distributed more equally over the year. The chief difference to be observed is that on the west coast spring rains prevail, and on the east coast summer rains, while in the middle of the colony the driest season is autumn, and in the south it is winter and spring. The contrast between the east and west coasts in the matter of rainfall is as striking as the difference in temperature. Thus in the North Island, Napier on the east has only half the amount of rain that falls in Taranaki on the west. But the Middle Island with its longitudinal range of lofty mountains exhibits this feature in a still more marked manner, for the rainfall on the west is nearly five times that on the east. The excess of precipitation on the coast is clearly illustrated by the distribution of the glaciers on the opposite sides of the range. Those on the west slope have an excessive supply of snow and descend to a line where the mean annual temperature is 50°, while on the east slope they descend only to the mean annual temperature of 87°. The winter snow line of the Southern Alps on the east side is 3,000 feet, and that on the west side 3,700 feet.

Periods of lasting drought are almost unknown in New Zealand, and only in two instances do the records show a whole month at any station without rain.

The configuration of the colony—its great length from north to south, compared with its breadth, its extent of coast line, and the division of the two principal parts by Cook Strait—renders it very subject to the influence of sea breezes. As a consequence, in parts of the country there is at times much motion in the atmosphere, and windy days are prevalent. Owing to the fact that most atmospheric disturbances pass from west to east with the centre of the depression to the south of New Zealand, there is a marked prevalence of Westerly winds throughout all seasons, but they are much modified by the form of the land. When the centre passes to the north of New Zealand, the result is that the North-east winds impinge on the east coast, bringing rain, followed by cold South-easters with heavy storms of rain and snow during winter in the south. The more common Westerly winds begin in the north-north-west with heavy rain on the west coast, and gradually veer to South-west, when fair bright weather sets in on that coast; but the same Southerly wind, sweeping along the east side of the islands, brings heavy strong weather locally known as "Southerly bursters," which from the shape of the coast reach the region of Cook Strait as South-east storms. All the other winds are either land or sea draughts, with light fine weather, or are moderate winds produced by the circulation of the atmosphere round anticyclonic areas of high barometric pressure, which are far more persistent in their influence than the fast moving cyclonic or low pressure areas. Wellington, by reason of its position near the narrowest part of Cook Strait, is peculiarly subject to wind.

Thunderstorms are most frequent where the changes of wind are most suddenly felt, from the most equatorial currents to the cold polar currents of the

South-west. On the west coast they are most frequent in spring, except in the extreme south-west of Otago, where during winter thunderstorms are of almost daily occurrence.

RECENT PUBLICATIONS.

American Meteorological Journal. A Monthly Review of Meteorology. October-December, 1893. Vol. X. Nos. 6-8. 8vo.

The principal articles are:—The Seiche in America: by E. A. Perkins (12 pp.). The Seiche is defined as being a movement of the water rhythmical, isochronous, and of decreasing amplitude, the result of a disturbance in the atmosphere.—The hailstorm of May 20th, 1893; by Prof. F. W. Very (11 pp.). This is an account of the thunder and hail storms which occurred in South Eastern Ohio, South Western Pennsylvania, and the northern part of West Virginia. In many places the hail stones were more than 2 inches in diameter, and caused a great amount of destruction.—Analysis of the causes of rainfall, with special relation to surface conditions: by G. E. Curtis (8 pp.).—The highest meteorological station in the world: by A. L. Rotch (6 pp.). This station, which is 16,650 feet above sea-level, is situated on Mt. Charchani, Peru, and is just below the permanent snow line. It is proposed to place there a set of self-recording instruments.—A loop in the track of an ocean storm: by E. Everett (6 pp.).—The mechanism of a tornado: by Prof. H. A. Hazen (4 pp.).—Hot winds in Texas: by A. Buell (4 pp.).—Mountains as storm breeders: by R. de C. Ward (3 pp.).—The winds of the Indian Ocean: by Prof. W. M. Davis (11 pp.).—South American Meteorology: by Prof. W. H. Pickering (4 pp.).—A South American tornado: by W. G. Davies (4 pp.). This is an account of the tornado which occurred on November 13th, 1891, and devastated the village of Arroyo Seco, situated on the railroad from Buenos Ayres to Rosario. In regard to the pressure and velocity of the wind, an approximate idea may be formed by the force required to throw down buildings and to raise and carry away railroad cars. Of the 21 box and flat cars standing upon the line and sidings, 17 were upset, some with their wheels in the air, others broken in pieces, and one loaded car, having a total weight of 14,000 kilogrammes, was thrown 80 metres to the west of the road. The freight shed measuring 26 by 10 metres, constructed of galvanised iron, was raised from its foundation, and turning over in the air was thrown against the station. Some of the plates of this building were found at Isla del Rio, a distance of over two miles. A most extraordinary feature was that the front wall of the station which received the blow of the shed suffered little damage, while the opposite wall, 50 centimetres thick, was so bent that it had to be rebuilt, and the interior partitions, 20 centimetres thick, were for the most part entirely thrown down. This phenomenon can only be explained by the difference in atmospheric pressure between the inside and outside of the building due to its sudden diminution outside at the first gust of wind, so that the air confined inside acquired for the moment an explosive force. Employing all available data, it results that the force of the two wind components (vertical and horizontal) exerted a pressure of 125 lbs. per square foot, but probably for a few seconds only.—Errors of the psychrometer: by Prof. H. A. Hazen (2 pp.). This is a criticism of Mr. Midgley's paper "Constructive Errors in some Hygrometers" which appeared in the *Quarterly Journal*, Vol. XIX. p. 197.

Annuaire de la Société Météorologique de France. Tome XLI., January-June, 1893. 4to.

The principal articles are:—Problèmes relatifs à la circulation générale de l'atmosphère: par H. Lasne (19 pp.).—Résumé des observations centralisées par le Service hydrométrique du bassin de la Seine pendant l'année 1891: par M. Babinet (30 pp.).—Notice relative aux chutes de neige de Janvier 1893: par V. Raelot (1 p.).—Résumé des observations magnétiques faites en Islande, à l'île Jan Mayen et au Spitzberg, en 1892, par MM. les officiers du transport *La Manche:* par T. Moureaux (4 pp.)

Indian Meteorological Memoirs: being occasional Discussions and Compilations of Meteorological Data relating to India and the Neighbouring Countries. Vol. IV. Part VIII. 4to. 1898.

This Part is devoted to an account by Mr. J. Eliot of the more important cold weather storms in India during the years from 1876 to 1891. From this discussion it appears that the cold weather storms are phenomena of an upper current in Northern India which forms an important part of the general circulation of the earth's atmosphere. So far as can be at present judged, they form in the plateaux and mountain areas of Upper India, Baluchistan, Persia and Afghanistan, and are hence apparently similar to the majority of the winter storms in the United States, which are said to form in the area to the west of the Rocky Mountains. It is possible the cold weather storms of India may be merely the redevelopment of shallow depressions travelling eastwards, but there is as yet little or no direct evidence in favour of this supposition. Their development and the peculiar features of the secondary depressions, and the dependent phenomena, have been explained by the relations between this upper current over Northern India and the influx of air from the equatorial belt, and by the action of the vast mass of the Himalayas and Afghan Mountains, and other geographical conditions, in modifying the cyclonic motion in India determined originally by the primaries. The phenomena of the warm waves and the dry cool waves which accompany them are to some extent of special effects determined by the conditions of the snowfall in the areas to the north-west and west of India. Their history shows the necessity for an early extension of meteorological observations in the long area between the field of European and of Indian meteorological work. It is doubtful whether it will be possible to trace the origin of these storms more definitely until international charts for the Northern Hemisphere, or at least for Europe, North Africa, and Asia, are prepared.

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. September-November, 1898. 4to.

The principal contents are: — Die Registrirungen des Moreland'schen Gewichtsbarographen von R. Fuess in Berlin: von Dr. Grossman (7 pp.). Weight barometers have never been much used in this country, the cost of King's, owing to the large quantity of mercury required, having effectually damped the ardour of intending purchasers. Dr. Grossman's paper gives us a carefully drawn up account on the advantages and disadvantages of the form of apparatus which has now acted for seven years at the Seewarte, Hamburg. The apparatus works by electricity, and Dr. Grossman admits that interruptions in registration are not uncommon.—Zur Dynamik der Atmosphäre: von M. Möller (11 pp.). This paper completes this treatise, which has been carried on for five months with intervals. At pp. 336-7 Dr. Möller gives the summary of all his conclusions.—Die klimatischen Grundgleichungen des Königreichs Sachsen: von Dr. P. Schreiber (9 pp.). This is a summary of a forthcoming paper in the third part of the *Klima von Sachsen* to appear next year.—Oliver Lodge über Blitzableiter und Blitzschutzvorrichtungen: von A. V. Obermayer (10 pp.). This is an abstract of Prof. Lodge's book, *Lightning Conductors and Lightning Guards*.—Die säkularen Temperaturschwankungen in Turin: von Dr. J. B. Rizzo (4 pp.). This is a discussion of the temperature records of Turin, which go back to the year 1753, with the view of testing the truth of Brückner's assertion that temperature follows a cycle of 35 years. Dr. Rizzo claims to have proved that his figures show a period of 19 years.—Ueber die Häufigkeit der Halo-Phänomene: von Dr. G. Hellmann (4 pp.). This paper shows that the ordinary idea that lunar halos are more common than solar ones is entirely incorrect. Dr. Hellmann maintains, from the figures he has been able to find, that solar halos are about five times as common as the lunar. Solar halos are most frequent from April to June, and least so in mid-winter. Lunar halos are most common in the winter half year. These results mainly are derived from the older observations at Upsala, and are confirmed by figures from New York and from Japan. It is much to be regretted that at most observatories no regular watch is kept on the sky, and thus many halos, &c. escape notice.

Mittheilungen des K. K. Militär-Geographischen Institutes. Band XII. 1892. 8vo.

Contains: Vergleiche von Quecksilber-Barometern mit siede-Thermometern: von H. Hartl (75 pp.). The author, who has already written several papers in the *Meteorologische Zeitschrift*, has printed this paper in defence of boiling point thermometers, which have of late years been rather under a cloud since the introduction of aneroids. He concludes that boiling point thermometers are at least as accurate as siphon mountain barometers, provided they have been accurately tested and the tube calibrated throughout its whole length. He holds that such thermometers are absolutely indispensable for all explorers making mountain ascents.

Symons's Monthly Meteorological Magazine. Vol. XXVIII. October-December, 1893. 8vo.

The principal articles are:—The Chicago Meteorological Congress (3 pp.).—Rainfall in Persia (4 pp.).—The British Association at Nottingham (3 pp.). This includes abstracts of several of the meteorological reports and papers read at the Meeting of the Association.—Sunspots and Air Temperature (1 p.).—The Drought and Heat of 1893: by P. Bicknell (1 p.).—October Raspberries and Strawberries (1 p.).—March to October 1893 (6 pp.). This is a comparison of the 1893 observations with those for the 10 years 1883-92, and shows the remarkable character of the past season.—The Minimum in Winter on the summit of Ararat (1 p.).

Weather Lore. A Collection of Proverbs, Sayings and Rules concerning the Weather. Compiled and arranged by Richard Inwards, F.R.A.S. 1893. 8vo. 200 pp. and 2 plates.

This is really the second edition of a little book which Mr. Inwards published in 1869. The present volume has been very neatly got up, and contains the most extensive and complete collection of weather lore yet published. It is accompanied by a plate illustrating the various cloud forms, together with their heights and names. It has also a bibliography of weather lore, and a very full index.

Zeitschrift der Gesellschaft für Erdkunde zu Berlin. Band XXVIII. 1893. No. 2. 8vo.

This contains a paper (30 pp.) by Dr. J. Hann on the Climate of Quito. The material which the author had at his disposal was extraordinarily scanty and sporadic; 3 months, not consecutive, between February and May 1871, and then 29 months, October 1878 to March 1881. Nothing but Dr. Hann's experience and his unremitting care in investigation could have enabled him to obtain any conclusions from such data. For instance, some of the data in the published records he dismisses as being absolutely fictitious. He finally obtains from Whymper's observations values for Guayaquil, and gives as his final result a mean value of the barometer at sea level at Guayaquil at 29·922 ins. As for temperature he finds that the old value of 60° given by Boussingault and quoted by Dove to be more than 3°·7 too high. The value Hann finds is 56°·3. In this connection Hann speaks of the value of earth temperatures at the depth of 3 feet, a method of observation which has been much neglected of late, but which in tropical countries gives an exceedingly accurate value for mean air temperature. Two separate observers at different times found respectively 56°·3 and 55°·8. A closer approximation to air temperature could hardly be expected, In conclusion, the climate of Quito is an eternal spring, and therefore equally trying to the residents as our own.

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ON THE CLIMATE OF SOUTHERN CALIFORNIA.

An Address delivered to the Royal Meteorological Society, January 17th, 1894.

BY C. THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

PRESIDENT.

(Plate I.)

THE subject of this, my valedictory address from the Presidential chair, is the Climate of Southern California, which, though largely studied by the Weather Bureau of the United States, is not so well known in England, and perhaps we chiefly derive our impressions of California from what the Americans call "the canning industry," which floods our stores and grocers shops with gaily coloured tins of preserved fruits and vegetables, the produce of that sunny and fertile land.

I propose, on the present occasion, to give you some account of the climate of this favoured region, gleaned during a visit in the autumn of 1892, when I investigated its present and future resources from an invalid point of view.

My conclusions are largely based on the publications of the Weather Bureau of the United States.

The entrance into California from Utah and Nevada is a welcome event for the passenger by the Union Pacific Express. After leaving Salt Lake City, the train for long hours skirts the shores of the great Salt Lake, with its numerous rocky islands rising hazily from its blue waters, and its back ground of snow-capped mountains, and then it plunges into the great American desert, a vast tract of alkaline soil growing nothing but sage scrub (*artemisia*) and inhabited only by Jack rabbits and lizards. There is no water save that tainted by alkali, and before the railway came many a traveller, man and horse, perished there from thirst, leaving their bones to whiten on the parched soil. The monotony of the landscape is broken by the remarkable cliff-like ranges of mountains in the distance, whose weird shapes, cleft precipitously, assume the forms of Grecian temples, of columns and altars and of towers, looking vivid and near in that transparent atmosphere. We traced out the Propylæum and the Theseum of Athens, and once towards sunset a red Sunium temple stood out boldly against the lemon sky. The railway stations, where may be seen a solitary cowboy in picturesque costume, or a few Indians lank and squalid, but clothed in gay colours, are rare, and are supplied with food and water by the passing trains, and during this journey we rescued a goods train, in difficulties from running short of coal, by taking it on with us to the next siding.

After several hours of this dreary waste one hails with joy the entry into the defiles of the Sierra Nevada, and the ascent to Summit Station, the highest point (7,042 ft.), and then the descent by the lovely blue Donner lake to the Pacific coast. The air at once becomes more balmy and is laden with fragrant odour of the conifers, and the eye wanders through vistas of densely wooded hills of considerable height, intersected with gorges and valleys, looking in the distance blue and mysterious; and in the depths could be discerned a silver stream threading its way to the ocean. The woods were of various kinds of fir, some of grand size, and, as in all American forests, there stand out a number of dead giants, with rich red trunks, the rugged sentinels of the Pacific. Next we came to fine oaks and cotton trees, acacias, sumachs, and maples, all, as it was November, in their brilliant autumn colouring, the prevailing hue being yellow here, in contrast to the vivid red we had left behind in the Eastern States. The little shanty cities began to lose their barrenness, balconies wreathed with plumbago and bright with roses and scarlet geraniums told of the south, and we soon reached vineyards with grapes and figs to sell at the more frequent stopping places, and so on past Sacramento, over the broad Oakland Ferry to San Francisco and the Golden Gates.

Some days later, after leaving San Francisco at 5.30 p.m., we next morning found ourselves passing through the Mojave Desert, a large tract of country destitute of water, and at present growing only sage scrub, cactus, aloe, and that extraordinary tree the yucca palm—a species of gigantic yucca, which attains a height of 20 to 40 ft., and stretches out its gaunt

irregular arms like a ghostly *araucaria*. It appears to be the characteristic tree of the arid regions, as we found it also in the Colorado Desert and in Arizona. This Mojave Desert is not of sand, but the soil is detritus of granite, rich in felspar and mineral phosphates, and it only needs a good supply of water to render it fertile, for parts, such as Antelope Valley, have already been converted into corn fields by irrigation.

Penetrating the Tehachapi Mountains, we emerged into the rich and fertile district of Southern California, and soon reached its capital, Los Angeles.

And now let me say a few words about the topography of the region.

California, as will be seen in any map of the United States, is a narrow strip of territory fringing the Pacific for nearly 1,000 miles, and extending over 10° of latitude, from 32° 30′ to 42° N.

Two ranges of mountains traverse the State from north-west to south-east, the western or coast range consisting of a series of low mountains running more or less parallel to the shore, and intersected by numerous valleys. The eastern range, the lofty chain of the Sierra Nevada, rises to over 13,000 ft., and is snow clad in parts, presenting almost an unbroken barrier to the east, for, according to Dr. Orme, of Los Angeles, "for nearly a thousand miles there is no pass lower than 5,000 ft. in height save where the Sacramento, Klamath, and Columbia Rivers have worn deep gorges through its rocky fastnesses."

Towards the south of the State the Tehachapi Mountains rise out of the St. Joaquin Plain and running east and west join the Coast and Sierra Nevada ranges, and south of this chain lies the territory of South California. This, as the map shows, forms an irregular parallelogram lying between 32°·30′ and 35°·40′ N lat., bounded on the east by the States of Nevada and Arizona, being separated from the last by the River Colorado after it has emerged from the grand Cañon and is on its way to the Gulf of California; on the south by New Mexico; on the north by the Tehachapi Mountains; and on the west by the Pacific. There is an irregular coast line sloping towards the south-east of about 330 miles, though the length of this district in a bee line is 230 miles. Its breadth is 330 miles.

From the Coast and Sierra Nevada chains run sundry lesser ranges, chiefly east and west, such as the Santa Ynes, the Sierra Pelona, the San Gabriel, and the San Bernardino, which rises in Old Grayback, to a height of 11,725 ft.

Southern California is divided into six counties, which starting from the north, are Santa Barbara, Ventura, Los Angeles, San Bernardino, Riverside, and San Diego, the most southerly.

The mountain shelter from the north and east may be described as tolerably complete, and the protected area consists of (1) valleys, chiefly running into the coast range from the sea, and rising to various elevations, such as the fertile San Fernando and San Gabriel Valleys, or else (2) more or less extensive plains, as those of Santa Ana and San Jacinto.

Southern California may be subdivided into two portions, eastern and

western, by the Sierra Nevada and its spurs, the San Gabriel and San Bernardino mountains.

The eastern portion consists of an arid region, called the Mojave and Colorado deserts, separated from each other by a low ridge of hills. This forms part of the great Basin, and the few streams which flow from the eastern side of the Sierra Nevada enter the Colorado river or lose themselves in the sink of the desert—most of the drainage flows to the Pacific.

The greater part of this desert tract, stands from 1,000 to 8,000 ft. above sea level, but there exist some great depressions, such as the Death Valley and the Sink of San Felipe, which are more than 100 ft. below the sea level and are supposed to have at one time formed part of the Gulf of California, but to have been separated from it later by a geological upheaval.

I do not propose to dwell much on the climate of the eastern portion of South California, but shall occasionally use it as a contrast to the climate of the western portion, and to demonstrate, how in the same latitude, and to a great extent with the same geological formations, the important conditions of ocean currents and shelter from cold winds, with a good supply of water, will convert a desert into a fruitful garden.

The climate of the *eastern* region is very dry, very hot in summer, and moderate in winter, and may be judged of by the returns of Fort Yuma at the extreme south of the Colorado Desert, where the mean temperature of the months of June, July, and August was 87°·1, and that of December, January, and February 54°·8. The average annual rainfall is 2·1 ins. At four stations in the Mojave Desert, Camp Cady, Barstow, Dogget and Fenney, the same state of things prevailed, the annual rainfall varying from 1 to 2 ins., and the summer heat being extreme; but this reaches its climax in the Death Valley, situate 175 ft. below sea level, where both heat and aridity are increased by the valley being narrow and deep, and enclosed by high and bare mountains. This has been reported to be the hottest place in the world. The valley derives its name from an unfortunate party of emigrants who in 1850 perished from thirst while attempting to cross it. It is 75 miles long and from 12 to 20 miles broad, and has been surveyed by various expeditions of the U.S. Government, and in 1891 a party encamped in the valley from May to September to study the summer conditions, and a report was issued by Prof. Mark W. Harrington, the present head of the Weather Bureau.

The temperature during the five months rarely fell below 70° and gave an average of 94°. It occasionally rose to 122° in the shade, and it has been stated by Mr. Spears to have once reached 137°. It is not only hot in summer, but consistently hot, and the heat is increased by burning blasts from the desert. The air was not stagnant, but in active motion. Heat and movement of the air together make the valley very dry and the relative humidity low. The range of temperature is nevertheless considerable, amounting to 28°. Men are reported to have been driven insane while trying to cross the valley, and a borax collector (there are large deposits of that product there) died suddenly with the water canteen in his hand. No men or beasts cross the valley now, save at night; and meat slaughtered

at night and cooked is spoilt in the morning; but if cut thin and soaked in brine it is cured in the sun in one hour. The maximum is higher than any figures noted in the Sahara, and is only equalled by the values for one station in India, Jacobabad in the Punjab.

The climate of the *western* portion of South California has three important factors.

1. Its southern latitude, which corresponds to that of the Empire of Morocco or of the French Province of Algiers in Africa.

2. The influence of the Pacific Ocean, and especially of the Kuro Siwo current, or Black Stream of the Japanese Seas. This current exercises the same warming and equalising influence on the Pacific coast of North America, as the Gulf Stream does on our western coasts and those of Norway, and, as Mr. Scott says, "it is to this stream that Sitka and the coasts of British Columbia owe their immunity from the ice which besets the shores of Asia in corresponding latitudes." A glance at any map of isotherms will show the effect of this current on the isothermal lines of North America in January and July, in the former case raising the temperature of the Pacific shores far above that of inland regions, and in July moderating the summer heat, and thus reducing the temperature. Very markedly so is this influence felt in the western part of Southern California, which at no point lies more than 60 miles from the Pacific and is largely open to its influence. The temperature of the water of the Pacific rarely falls below 60°, or rises above 70°.

3. The influence of mountain ranges. One effect is undoubtedly protection from Northerly and Easterly blasts which the double range of mountains renders very complete. The other effect is the condensation of moisture from the vapour-laden winds blowing from the Pacific. This accounts for the increased rainfall of this region, though this is less than that of Northern California. The existence of the Mojave and Colorado deserts may be due to their lying, like the American desert, to the leeward of the mountains, and thus being shut off from the influence of moist winds.

We may now consider the principal features of the climate of this region.

According to Dr. Orme, to whom I am largely indebted for information, both from his works and his conversations with me, the rainfall is about 16 ins. a year, the annual amount varying greatly as to year and locality, and contrasting strongly with that of the eastern basin, noted at Fort Yuma, as the subjoined table will show.[1]

ANNUAL RAINFALL.

	Ins.
Santa Barbara, northern coast	16·92
Los Angeles, 16 miles inland	17·95
San Bernardino, 60 miles inland	16·85
Fort Yuma, Colorado Desert	2·10

[1] Orme, *Climate of Southern California.*

The distribution of the rainfall during the decade from 1881-1890[1] for three stations, Los Angeles (inland), San Diego (coast), and Riverside (60 miles inland) show great irregularity, but altogether a moderate amount.

Years.	Los Angeles.	San Diego.	River-side.
	Ins.	Ins.	Ins.
1881	5·53	5·00	3·95
1882	10·74	9·24	5·78
1883	14·14	8·01	5·58
1884	40·39	26·95	25·32
1885	10·69	5·72	5·15
1886	17·22	15·39	8·02
1887	16·07	10·72	7·81
1888	21·04	11·57	15·48
1889	33·31	16·03	20·41
1890	12·49	8·2	11·53
Mean	18·16	11·62	10·90

The mean relative humidity on the coast varies from 69 to 75 per cent. in the winter months, and from 60 to 68 per cent. in the summer. The annual mean percentage (11 years) for San Diego (coast) is 74·7, that for Los Angeles (inland) 69 per cent., while in summer it falls at Fort Yuma to 85 per cent.

The rainfall is distributed over the months of October to April, and in January there may be as many as five rainy days successively. Los Angeles counts about 42 days in which an appreciable amount of rain falls, and San Diego 41 days, Riverside 40 days. The sun shines on an average on 300 days out of the year, and for 179 days without a cloud, but there are 47 cloudy days, and on the so-called fair days fogs and mists are occasionally noted; indeed a bad feature of this climate are the mists which come up suddenly from the Pacific and envelope everything in a cold damp atmosphere. One hot sunshiny day I was standing in the Lake Park of Los Angeles, looking at the fine view of the Sierra Madre Mountains, when suddenly I was enveloped in a thick cold mist, which shrouded the whole scene and made me shiver. Two days later at Santa Barbara the phenomenon was repeated. It was a blazing hot day, and we were inspecting Santa Barbara from the train, or cars as they say in America, when suddenly a chilly feeling came over us and Santa Barbara disappeared in fog. This only lasted for a few minutes, the sea-mist as it passed moving further inland. These mists do not appear to deposit much moisture, but are bitterly cold. They always come from the Pacific, but are stated to be limited to the lower ground, and never to rise above 1,000 ft.

The mild temperature and the relative equability of Southern California are its great attraction, and its climate has been spoken of as one of perpetual spring, but the figures, and certainly my impressions in November, rather

[1] Davidson, *The Climate of South California*.

indicate a climate of perpetual summer. The mean temperature of Los Angeles and Riverside for 1890 was 63°, for San Diego 62°·6, and for Santa Barbara 60°·2.

The monthly means for 11 years at Los Angeles, San Diego and Santa Barbara are given below and show remarkable equability.

Months.	Los Angeles.	San Diego.	Santa Barbara.
	°	°	°
January ..	52·5	52·8	52·5
February	54·3	54·3	54·7
March ..	56·3	56·0	55·9
April	59·0	58·6	58·6
May	62·2	61·3	59·6
June	66·0	64·4	62·9
July	69·2	67·2	65·9
August ..	70·2	69·1	67·0
September	68·4	67·2	66·6
October..	63·1	62·6	62·9
November	59·0	58·5	59·4
December	55·7	56·5	55·8
Year ..	61·3	60·7	60·1

The highest temperature recorded at Los Angeles was 105°, and the lowest 28°, but at San Diego the corresponding figures were 101° and 32°, a difference due possibly to its situation on the coast.

Frost is of very rare occurrence, except on some of the low lying marshy grounds, or again high up on the mountain slopes. Indeed with the multitude of subtropical crops, the effects of frost are soon visible and fearfully destructive, as has been seen, though fortunately seldom at Riverside. The heat in summer is occasionally great, but not excessive as in the neighbouring desert; and beyond "camping out," which is a great delight to Californians, many never go to any distance from their homes.

At Fort Yuma, our standard of comparison, during the year 1880 the temperature exceeded 100° for 78 days, on 28 of these the mercury rose to 110° and higher.

As I have before said these temperatures are well borne in the exceedingly dry atmosphere and work is carried on as usual; sunstroke is unknown.

While the difference between monthly means is small, there is occasionally considerable range between the maxima and minima, as in 1890, when the range was 71° at Los Angeles, 63° at San Diego, and 64°·5 at Santa Barbara.

The winds according to Dr. Orme during the summer have the prevailing directions from the North and North-west, and in winter from the South and South-west, and are generally of a refreshing character, but taken as a whole the winds are Westerly.

There are certain local winds, and among them the Norther, Chinook, or Santa Ana as it is called in Southern California, a remarkably dry current generally local in its prevalence, but occasionally making itself felt over large districts. While it blows the air becomes highly electrified, horses tails stand

out like thick bushes, the hair crackles when stroked, and metallic objects duly insulated give forth electric sparks if a conductor is brought near. Nevertheless the Santa Ana wind is reported to be followed by a specially pure and invigorating atmosphere.

It will be seen that the climate of South California is a warm, temperate, and on the whole an equable one, with more moisture than that of Colorado, the subject of my last year's address, and a climate which would allow of much out-door life all the year round.

We will next consider its effect on vegetation and take a glance at the results of diligent watering and gardening in this beautiful region.

Our first excursion from Los Angeles was to Santa Barbara on the coast, at the northern extremity of South California, though with a due southerly aspect. After 4½ hours by rail through a rich plain in which oranges, figs, plums, and grapes are produced in great abundance, we came to the Pacific at Ventura and ran along it into Santa Barbara, a flourishing little town of 6,000 inhabitants, embosomed in orange and lemon groves backed by hills covered with vineyards, and protected to the north and east by the Santa Ynes range.

The vineyards of Santa Barbara are of comparatively ancient date, as they were planted by the Franciscan monks, who introduced the culture of the vine and of the olive in 1769, and did much to civilise and christianise the native Indians. The Spanish Fathers established missions at Santa Barbara, Santa Monica, San Diego, San Gabriel, and other places, erected graceful churches and conventual buildings, and fortunately named the places in which they settled in the beautiful Spanish language, and thus stamped the country with a picturesqueness which the modern American could not have supplied. Their buildings, made of the baked clay or adobe of the neighbourhood, are always simple and in good taste, and show how much beauty of form can be obtained with poor material, while the ruins, clothed with the semi-tropical luxuriance of nature, delight the eye.

Santa Barbara has a port with a wooden pier, and has abundance of street cars, electric and others, and some fair hotels, besides plenty of villas in gardens, and ranches in the neighbourhood which are the best places for invalids. It is a famous place for flowers, and a floral festival is held in April, when there are processions of flower-bedecked carriages and cars like the *bataille des fleurs* at Cannes and Nice. The roses grow in great profusion, and the arum, called by the Californians the calla lily, is largely cultivated and the bulbs exported for the eastern market. It would be impossible for me to go into the subject of floriculture, but the land is apparently able to produce any flowers, though as fruit is so profitable, this department is at present kept in the background.

Along the coast we come to Santa Monica and San Pedro, both centres of rich luxuriance of vegetation, and gay little Redondo Beach, and then by the surf line we reach Ocean Side, another modern sea-side place. Near this spot I witnessed the most gorgeous sunset I have ever beheld. I have seen beautiful sunsets in Italy, Sicily, Greece and Spain. I have seen northern ones of great splendour, but anything to equal this Pacific one I do not

remember. The sun sank into a deep green ocean lit up with golden light, which imparted a remarkable transparency, as of liquid flame. Above was a sky red as a furnace, out of which rose like incandescent masses the picturesque islands of Santa Catalina and San Clemente. The red gradually faded into the usual pearly sunset tints, but the ocean retained for a considerable period its wonderful green hue. The weather was fine and warm, 88° to 84° in the shade, and there had been no rain for months.

The next place of importance, with its magnificent harbour, is San Diego, the second port of California, situated close to the frontier and within full view of the Mexican mountains, which at Coronado are only 12 miles distant.

San Diego was the first mission of the Franciscan Fathers, and is now a flourishing town of 16,000 inhabitants of the usual American type. San Diego County, probably because of its southern position, has been found to be specially suitable for the growth of the lemon, and in addition to the lemon groves now established, it is proposed to bring, by means of irrigation, 150,000 acres of "frostless" ground into cultivation for this tree, by means of gigantic dams, such as the Hemet, Sweetwater and others. The San Diegians calculate on being able to irrigate 250,000 acres in time. However, my object was less to see San Diego itself than Coronado Beach and its famous hotel. This we reached by crossing the harbour to the narrow spit of sandy land which separates it from the ocean. We landed from our steam ferry and were taken to the hotel by a steam tram through a garden abounding in exotics, and, curious contrast in this frequented spot, there was plenty of wild life, for outside the botanical garden, as it is called, are numerous Jack rabbits and cotton tails (ordinary rabbits), while on the shore shooting of canvas-backed ducks was going on.

The hotel is built in irregular lines, and stands at a short distance from the beach, commanding fine views in all directions to Point Loma and to the town and harbour of San Diego, backed by the San Jacinto and San Bernardino ranges, and the Mexican Table Mountain. There is a fine expanse of the Pacific, rising out of which are the small Coronado Islands which belong to Mexico.

The hotel is a picturesque building which covers 7 acres and is entirely built of wood. It contains 1,200 beds and a considerable number of public and private sitting rooms, and is surrounded by terraces both open and covered; there is also a large quadrangle sheltered from all wind but open to the sun and planted as a garden. Here grow many beautiful exotics, the guava tree, the scarlet hibiscus, the rosa sinensis, the stephanotis, the loquat or Japanese medlar, and the persimmon; many varieties of palms; such as the Seaforthia, which we admire in the large hothouse at Kew, the coco plumosa, the Washingtonia philaferia, the Kentia, and the oreodoxa or Royal palm. The Bougainvillea, as everywhere in South California, covers the walls with gorgeous sheets of colour, and the heliotrope scents the air. Lastly, the scarlet poinsettias attain to the size of trees, and reminded me of those I had seen growing in the Latomia of Syracuse in Sicily.

Coronado Beach has good salt baths, and from what Dr. Raphael Lorini,

the resident medical man, told me it is largely patronised in the winter by people from the Eastern States, especially Bostonians, who suffer from the exhaustion of city life. The temperature, even in the middle of November, was here, as generally during my sojourn in South California, 83° to 84° in the shade for the midday hours, and the evenings cool and refreshing, the air dry and clear.

Among the attractions of Coronado is an ostrich farm, similar to those at Santa Monica and Santa Barbara. The birds are often vicious and have kicked some of their attendants to death, but the experiment of ostrich breeding is interesting and promises to succeed.

The whole inland district from the Pacific Coast to the San Gabriel and San Bernardino mountains, and far up the slopes of these ranges, is cultivated and for the most part irrigated, as we saw on our return to Los Angeles from Coronado Beach. The principal inland towns in addition to the capital are Santa Ana, Colton, Riverside, Pomona, San Bernardino, all prosperous centres of fruit, flower and vegetable growth, and with plenty of railway communication, for no less than ten lines radiate from Los Angeles in all directions. Los Angeles is a well-built city of some 60,000 inhabitants and stands about 300 feet above sea level, commanding a fine view of the Sierra Madre mountains.

The charms of the place are its numerous parks or public gardens tastefully laid out with palms, pepper trees, magnolias and other beautiful trees and shrubs, as well as with gay flower beds. The streets are chiefly paved with asphalt and of course pervaded by the eternal cable and electric cars, the houses are handsome and many are surrounded with gardens, so that the effect is pleasing. Having already sketched the chief features of the climate I shall only add that the hotel accommodation at Los Angeles is fairly good and that there is an interesting and instructive museum of all the productions of South California, vegetable and mineral.

The desirable winter residence is Pasadena, 8 miles to the north of Los Angeles in the San Gabriel valley, on the slopes of the Sierra Madre and in the midst of orange groves, with magnificent avenues of pepper trees and specially well tended gardens. This small town of 12,000 inhabitants, 900 ft. above sea level, will be shortly connected by a log wheel railway with the summit of Mount Lowe, 7,000 ft., one of the Sierra Madre heights, which is snow capped in winter; and thus the Californians will be able to tramp through the snow on Mount Lowe and after 30 minutes railway descent to pick roses at Pasadena.

The view from the Raymond Hotel is extensive and beautiful; one gazes over a vast garden bordered by the Pacific, of which a glimpse is obtained at San Pedro, to the north rise the Sierra Madre and behind these Old Baldy, one of the San Bernardino range, rising to 10,142 ft. and tipped with eternal snow.

We contemplate a wonderful mass of luxuriance at our feet, orange and lemon trees, the older ones larger than those of Southern Europe, loquats, Japanese persimmons, loaded with ripe fruit, olives and palms, as well as the

ever present eucalyptus, mingled with cherries, apricots, peach, and nectarine standards, and then to think that 20 years ago all this was a sheep pasture with a lonely ranch which irrigation, in this fine climate has converted into a Garden of Eden.

Further east on the slopes of the same range lies a charming hotel called the Villa Sierra Madre, embosomed in olives and oranges, 1,800 ft. above sea level, with 100 beds and all arrangements for invalid residence. Here I was hospitably entertained by my friend and patient Dr. Gresham, late of Bromley, and spent an agreeable day in exploring the district. From thence to the San Bernardino Pass is a series of gardens which flourish apparently in proportion to the amount of irrigation. This is carried on either by leats, *i.e.* by conducting mountain streams in channels or by tunnelling into the mountains for water, or, in the lower grounds, by sinking artesian wells.

It is remarkable that in this warm climate that with so much water artificially spread over the land, there appear to be no malarial fevers.

Riverside (population 4,683) lies in the plain, away from the mountains, and has the reputation of being the best irrigated and cultivated tract of the whole region. The yield in oranges in 1890 was 358,341 boxes, the varieties grown being chiefly the Australian navel orange and the seedless Washingtons. Vines are grown for raisins; raisin exportation appears to be more profitable here, wine is made in other parts of South California. Riverside possesses its famous magnolia avenue 12 miles long and 125 ft. wide, lined with exotics, with the orange groves on each side.

Besides the fruits already mentioned, Southern California produces such subtropical ones as the cherimoyer or custard apple, the pineapple, the banana, and among our English fruits strawberries all the year round, raspberries, blackberries, currants, mulberries, quinces, apples, pears, cherries, and figs, the only difference being that the seasons of most fruits are longer there than here. Pumpkins and melons of all kinds abound.

Wheat yields an abundant crop, and has averaged on some large ranches a harvest of 1 ton to the acre, but 1,800 lbs. is considered a satisfactory yield. Barley also is largely grown in the southern part of the State, and more than a million sacks are produced yearly. This and wheat are grown without irrigation.

Alfalfa, or lucerne, generally requires artificial water supply, but with this will give from 3 to 6 crops a year, with an average of 1 to 2 tons to the acre for each crop.

In Ventura County beans are the staple commodity, and elsewhere beet is cultivated and sugar made from it.

Lastly, another large branch of industry are the bee farms, the product of which we see in the Californian honey, the special flavour being due to the bees feeding on white sage.

So much for the effect of the climate on vegetation.

Man appears very healthy and happy. The death rate of Los Angeles is 12 per 1,000, a very low one, though it contains a large proportion of deaths from consumption, owing to the number of invalids who flock to this

country. I have known several who have done well; but to attain satisfactory results patients must not visit it for a winter and then return eastward, but should make it their home, and if possible take to some occupation involving an open air life, like gardening or fruit farming, returning to less complex conditions than those of city life. Many who have done so have greatly prospered in health and pocket.

In conclusion, the climate of Southern California seems to be characterised by

1. A warm sunny atmosphere all the year round, permitting much outdoor life and camping out in summer.
2. Remarkable equability of temperature, daily, monthly, and annual.
3. Abundance of sunshine at all seasons of the year.
4. A moderate rainfall and a small number of rainy days, occurring chiefly in winter and spring.
5. A fair relative humidity percentage, evenly distributed over the whole year.
6. The prevalence of fog, or sea mist, from time to time rolling in from the Pacific Ocean, but not reaching the higher lands.
7. A porous soil, which when supplied with abundant water by American energy, seems capable of producing extraordinary crops of grains, fruit, and vegetables.

REPORT OF THE COUNCIL

FOR THE YEAR 1893.

In presenting their Report, the Council have to congratulate the Society on its steady and uninterrupted progress during the past year. There is an increase in the number of Fellows elected over the number elected in 1892, and the balance at the Society's Bankers at the end of the year is larger than the balance brought forward from 1892.

The Council feel that the Society will regret the numerous losses by death sustained during the year, and particularly those of Lord Ebury, Thomas Hawksley, William John Harris, George Matthews Whipple, and Henry Francis Blanford.

The death of Lord Ebury, on November 18th, removes one of the small band, still remaining, of those who took part in promoting the foundation of the British Meteorological Society. Lord Ebury, then Lord Robert Grosvenor, was, in 1838, a Member of the Council of the original Meteorological Society of London. At the Anniversary Meeting of March 12th, 1839, he was elected its President, and continued to hold that office until the Society was dissolved, on August 14th, 1850. The British (now the Royal) Meteorological Society was founded on April 3rd, 1850, and Lord

Ebury joined it on May 7th following. He was then elected one of its Vice-Presidents, a position which he occupied until May 27th, 1856. From this date he occasionally attended its meetings, and ever showed an interest in its welfare.

The late Thomas Hawksley, F.R.S., Past President of the Institution of Civil Engineers, joined the Society on January 22nd, 1856, and during his long career as one of the most distinguished Civil Engineers was always a keen supporter of the science of Meteorology.

The late William John Harris, M.R.C.S., of Worthing, joined the Society on November 20th, 1867, and served on the Council for 1875. He will be chiefly remembered as being the Society's observer at Worthing, where he commenced his records in 1867, and continued them till his death on August 28th, 1893, a period of over 26 years. These observations, through the great courtesy of Mrs. Harris, are now being continued by Mr. G. B. Collet.

The late George Matthews Whipple, B.Sc., F.R.A.S., joined the Society on April 15th, 1874, and was a most energetic worker. He was employed at the Kew Observatory from October 1858, and held the post of Superintendent from 1876 until his death. He served on the Council from 1876 to 1887, and contributed no fewer than 22 papers to the *Quarterly Journal*. He died at his residence at Richmond on February 8th, 1893.

The late Henry Francis Blanford, F.R.S., F.G.S., who had achieved a high reputation as Meteorological Reporter to the Government of India, joined the Society on November 20th, 1878, served on the Council from 1888 to 1891, and he did good work as a member of the Editing Committee. He died at Folkestone on January 23rd, 1893.

The loss of such men, together with the other serious losses by death mentioned later on, have left a great void, which it will be difficult to fill.

Of those who were either Founders (marked *) or were elected in the first year we still have with us the following Fellows:—

Brown, Isaac, F.R.A.S.	Perigal, H., F.R.A.S.
*Glaisher, J., F.R.S.	Prince, C. L., F.R.A.S.
Hippisley, J., F.R.S.	*Slatter, Rev. J., F.R.A.S.
*Johnson, W., F.R.A.S.	Tudor, E. O., F.S.A.
*Lowe, E. J., F.R.S.	

The Council have been materially assisted by several Committees, which were constituted as follows:—

General Purposes Committee. - President, Secretaries, Foreign Secretary, Treasurer, Messrs. Ellis, Inwards, and Latham.

Editing Committee.—Messrs. Inwards, Maclear, and Scott.

Wind Force Committee.—President, Secretaries, Messrs. Binnie, Chatterton, Curtis, Dines, C. Harding, Laughton, Munro, and Scott.

Standing Referee on Papers.—Mr. Ellis.

Instead of the Annual Exhibition of Instruments, which has now been a feature of the Society's Session for the past 13 years, at the request of the Council, Mr. Shelford Bidwell, F.R.S., delivered a lecture on "Some Meteo-

rological Problems," illustrated by numerous electrical experiments. The lecture was extremely well attended.

Stations.—Observations have been accepted from the following new stations:—Chester; Cranleigh, Surrey; Folkestone, Kent; Halstead, Essex; Lancaster; Newport, Pembrokeshire; and Newquay, Cornwall. The observations have been discontinued at Babbacombe and Exeter.

Copies of detailed monthly returns and annual summaries of results have been supplied as usual to the Meteorological Office.

Inspection of Stations.—All the stations north of latitude 52° N. and east of longitude 2° W., together with such other stations west of longitude 2° W. as were not inspected last year, have been visited, and found to be on the whole in a satisfactory condition. Mr. Marriott, in his Report (which will be found in Appendix III., p. 100), states that he has called the special attention of the observers to the working of the wet bulb thermometer, particularly during frost.

Dinner to Mr. Perigal.—A Congratulatory Dinner at Limmer's Hotel, on Saturday, April 15th, was, on the initiation of the Society, given to Mr. Perigal, in celebration of his 92nd birthday and of his 40 years' service to the Society as Treasurer.

Research Fund.—Dr. C. Theodore Williams, previous to vacating the office of President, has expressed a desire for the formation of a fund for carrying out experiments and observations in Meteorology, and has generously presented the sum of £100 to form the nucleus of a Research Fund. The Council have gratefully accepted this donation, and trust that this Fund may be augmented by interest and otherwise as time goes on, and that it may be the means of forwarding the objects of the Society in future.

Donations.—A valuable present of a lime-light lantern and all the necessary apparatus for use in illustrating the papers read at the Society's Meetings has been received from the President. Considerable additions have been made to the Library during the year, a list of which will be found in Appendix V., p. 113. Several Photographs have been received from different donors.

Quarterly Journal.—This publication has contained several interesting papers, amongst which are "The High Altitudes of Colorado and their Climates," by the President; "Remarks on the Measurement of the Maximum Wind Pressure, and description of a new instrument for indicating and recording the same," by Mr. Dines; "The relation between the duration of Sunshine, the amount of Cloud, and the height of the Barometer," and "The Mean Maximum and Mean Minimum Temperature of the Air on each day of the year at the Royal Observatory, Greenwich, on the average of the fifty years, 1841-90," by Mr. Ellis; "Suggestions, from a practical point of view, for a New Classification of Cloud Forms," by Mr. Gaster; and "Fifteen Years' Fogs in the British Islands, 1876-90," by Mr. Scott.

Meteorological Record.—This publication has been brought up to June 1893.

Phenological Report.—This interesting and instructive Report was read

by Mr. Mawley at the February meeting, and it is satisfactory to find that the number of observers has been well maintained.

The New Offices.—These continue to give satisfaction, and have proved very convenient.

Hour of Meeting.—In view of the repeated requests of numerous Fellows, the Council resolved to alter the hour of Meeting for the current Session from 7 p.m. to 8 p.m., a change which they trust will be conducive to the comfort of the Fellows, and lead to a larger attendance at the Meetings.

Fellows.—The changes in the number of Fellows during the year are exhibited in the following table, which shows an increase of three:—

Fellows.	Annual.	Life.	Honorary.	Total.
1892, December 31st...	399	137	19	555
Since elected	+43	+1	...	+44
Deceased.....	− 8	−3	−2	−13
Retired	−19	...	...	−19
Lapsed	− 3	...	...	− 3
Defaulters	− 6	...	...	− 6
1893, December 31st...	406	135	17	558

Deaths.—The Council have to announce with much regret the deaths of eleven Fellows, and of two Honorary Members. The names are:—

John Charles Bell, F.R.G.S.	elected Feb. 15, 1888.
Henry Francis Blanford, F.R.S., F.G.S.	,, Nov. 20, 1878.
Edith Brooke	,, Dec. 19, 1883.
Sir Andrew Clark, Bart., M.D., F.R.S., Pres.R.C.P.	,, Apr. 20, 1892.
Prof. Daniel Colladon (Honorary Member)	,, May 16, 1888.
Prof. Henri Marié Davy (Honorary Member)	,, Apr. 17, 1878.
Earl of Derby, K.G., M.A., LL.D., F.R.S.	,, Mar. 19, 1879.
Lord Ebury, F.R.G.S.	,, May 7, 1850.
William John Harris, M.R.C.S.	,, Nov. 20, 1867.
Thomas Hawksley, F.R.S., M.Inst.C.E., F.G.S.	,, Jan. 22, 1856.
Captain John Shortt, R N.	,, Dec. 18, 1889.
Lieut.-Col. William Stuart	,, Nov. 20, 1878.
George Matthews Whipple, B.Sc., F.R.A.S.	,, Apr. 15, 1874.

APPEN-

STATEMENT OF RECEIPTS AND EXPENDITURE

Receipts.

	£	s.	d.	£	s.	d.
Balance from 1892				142	11	4
Subscriptions for 1893	685	2	0			
Do. former years	62	15	0			
Do. paid in advance	36	2	0			
Life Composition	21	0	0			
Entrance Fees	35	0	0			
				889	19	0
Meteorological Office—Copies of Returns	143	10	3			
Do. Grant towards Inspection Expenses	25	0	0			
				168	10	3
Dividends on Stock (including £40 5s. 8d. from the New Premises Fund)				114	13	8
Sale of Publications				32	[illegible]	1

PENDIX I.

FOR THE YEAR ENDING DECEMBER 31ST, 1893.

EXPENDITURE.

	£ s. d.	£ s. d.
Balance due to the Assistant-Secretary		2 5 6
Journal, &c.:—		
Printing Nos. 85 to 88	105 10 6	
Illustrations	45 0 8	
Authors' Copies	16 16 6	
Meteorological Record, Nos. 47 to 50	50 9 6	
Registrar-General's Reports	8 8 0	
		226 5 2
Printing, &c.:—		
General Printing	24 1 6	
Stationery	5 4 1	
Forms	11 3 6	
Books and Bookbinding	28 18 1	
		69 7 2
Office Expenses:—		
Salaries	417 5 5	
Rent and Housekeeper	141 14 0	
Furniture, Repairs, Coals, &c.	15 9 10	
Postage	47 12 0	
Petty Expenses	16 0 11	
Refreshments at Meetings	14 1 1	
Lecture Expenses	12 1 0	
Subscriptions overpaid returned	4 0 0	
		668 5 3
Observations:—		
Inspection of Stations	54 0 7	
Observers at Old Street and Seathwaite	7 2 0	
Instruments	4 15 7	
		65 18 2
Stock:—		
Purchase of £100 2½ per cent. Annuities		97 5 0
		1129 6 3
Balance:—		
At Bank of England	165 13 3	
In hands of the Assistant-Secretary	2 17 1	
		168 10 4
		£1297 16 7

Examined and compared with the Vouchers, and found correct,

J. S. HARDING, JUNR., } *Auditors.*
ALBT. E. WATSON, }

January 9th, 1894.

APPEN-

ASSETS AND LIABILITIES

Liabilities.

	£	s.	d.
To Subscriptions paid in advance	36	2	0
„ Excess[1] of Assets over Liabilities	2751	7	11
	£2787	9	11

[1] This excess is exclusive of the value of the Library and Stock of Publications.

NEW PREMISES FUND,

	£	s.	d.
Amount paid to the Society's Funds towards the increased rent of the New Premises	40	5	8
Amount invested in purchase of £13 8s. 10d. South Australian 3½ per cent. Inscribed Stock	12	10	0
	£52	15	8

DIX I.—Continued.

ON JANUARY 1ST, 1894.

ASSETS.	£ s. d.	£ s. d.
By Investment in M. S. and L. R. 4½ per cent. Debenture Stock, £800 at 142	1136 0 0	
„ Investment in N. S. W. 4 per cent. Inscribed Stock, £654 18s. at 104¼	682 14 8	
„ Investment in L. & N. W. R. Ordinary Stock, £200 at 164	328 0 0	
„ Investment in 2½ per cent. Annuities, £100 at 97¼	97 5 0	
		2243 19 8
„ Subscriptions unpaid, estimated at	50 0 0	
„ Entrance Fees unpaid	10 0 0	
„ Interest due on Stock	30 3 10	
		90 3 10
„ Furniture, Fittings, &c.	184 19 10	
„ Instruments	99 16 3	
		284 16 1
„ Cash at Bank of England	165 13 3	
„ Cash in hands of Assistant-Secretary	2 17 1	
		168 10 4
		£2787 9 11

J. S. HARDING, JUNR., ALBT. E. WATSON, *Auditors.*
WILLIAM MARRIOTT, *Assistant Secretary.*

January 9th, 1894.

DECEMBER 31ST, 1893.

	£ s. d.
Contributions of Fellows	12 10 0
Interest received on investment	40 5 8
	£52 15 8

NOTE.—The Society holds on account of this Fund £1199 0s. 2d. South Australian 3½ per cent. Inscribed Stock.

J. S. HARDING, JUNR., ALBT. E. WATSON, *Auditors.*
WILLIAM MARRIOTT, *Assistant Secretary.*

January 9th, 1894.

APPENDIX II.

Subscriptions promised towards the New Premises Fund.

FOURTH LIST.

	£	s.	d.
Amount already promised	1,176	7	6
Mr. O. B. Cuvilje	2	0	0
	£1,178	7	6

APPENDIX III.

Inspection of Stations, 1893.

During this year I have visited all the stations north of 52° N. lat., and east of 2° W. long., together with such other stations west of 2° W. long. as were not inspected last year.

The stations as a whole were in a satisfactory condition, and the observers appear to take an intelligent interest in the work. Fewer changes than usual have occurred in the zeros of the thermometers.

This year I took with me some brass back-plates having a hole and slot for suspending the thermometers. These I substituted, where necessary, for the back-plates having only a ring, in order to obviate the vibration of the maximum and minimum thermometers in windy weather. I also renewed the metal fastenings for holding the thermometer tubes when they were almost or quite worn away.

The observers have been urged to give as much attention as possible to the working of the wet-bulb thermometer, especially during frost.

I have to report that the charge of the observations at Blackpool has been transferred from the Borough Surveyor to the Medical Officer of Health. The instruments have also been removed to property belonging to the Corporation, and there is every reason to expect that the observations will be thoroughly satisfactory.

WILLIAM MARRIOTT.

October 18th, 1893.

NOTES ON THE STATIONS.

APPLEBY, *August 26th.*—The instruments were all clean and in good order. I rearranged the position of the water receptacle, and urged the observer for the future to read the thermometers to tenths instead of to whole degrees.

BELPER, *September 2nd.*—The instruments were in the same position as formerly, the thermometer screen being greatly sheltered by trees. I put on fresh back-plates to the minimum thermometer. The amount of cloud seems to be somewhat under-estimated.

BLACKPOOL, *August 30th.*—The charge of the instruments and the observations had recently been transferred from the Borough Surveyor to the Medical Officer of Health. Mr. F. Pool, one of the Sanitary Inspectors, is the observer, and he appears to be an efficient man. The rain gauge was sheltered by a row of willow bushes. In order to get the instruments together on Corporation land, I went to the Sanatorium and selected a fresh site, which will be more open and satisfactory than the present one.

BOLTON, *August 31st.*—The thermometers were all correct, except the minimum, which had gone down 0°·3. The funnel of the rain gauge required repairing. Observations with a 6 inch earth thermometer were commenced on January 1st.

BURTON ON-TRENT, *August 1st.*—All the instruments were in good order, except the grass minimum, which had 1° of spirit at the top of the tube.

BUXTON, *September 1st.*—The observations are now made by the Medical Officer of the Devonshire Hospital, and are more efficiently taken than formerly. The thermometers were all correct. The results from the sunshine recorder would no doubt be better if the instrument were placed in a more satisfactory position.

CHEADLE, *July 31st.*—The instruments were in good order.

CHESTER, *July 29th.*—The instruments are mounted in a small garden in the Park Gate Road, the exposure is very fair but somewhat confined. The thermometers required rearranging in the screen, and also holes to be cut behind the bulbs of the maximum and minimum. None of the thermometers except the grass minimum had been verified at Kew. [The instruments have subsequently been sent to Kew for verification.]

CORTON, *July 19th.*—The sunshine recorder is by Messrs. Negretti and Zambra, and is placed in a well exposed position near the cliff.

DRIFFIELD, *July 13th.*—Everything was in good order, and the thermometers were all correct. Mr. Lovel had added a barograph and evaporation tank to his equipment since the last inspection. [Mr. Lovel died on February 16th, 1894, but the observations will be continued by his father, Mr. W. E. Lovel.]

GELDESTON, *July 20th.*—The sunshine recorder is mounted on the ridge of a stable, and is very well exposed. A tree on the east is the only thing likely to at all intercept the sun's rays.

HALSTEAD, *September 27th.*—The instruments are placed on a grass plot in a kitchen garden, and are well exposed. I recommended an alteration in the mounting of the dry and wet thermometers. The dry and wet had both gone up 0°·2.

HARROGATE, *July 11th.*—Since the last inspection the instruments have been removed from the West End Park to the Bog Valley Gardens. They are in a good situation, and are well exposed. The observations are now under the charge of Mr. J. Farrah. The sunshine recorder (Jordan pattern) is placed on the top of the tower of the Hydropathic Establishment, and is very well exposed.

HILLINGTON, *July 18th.*—The thermometers were all correct. The sunshine recorder was not quite level. This I endeavoured to adjust.

HODSOCK, *September 4th.*—This station was in good order. The ball of the sunshine recorder was not quite in the centre of the frame. This I adjusted, and Mr. Mellish has had the slate slab fixed in cement.

KENILWORTH, *August 2nd.*—Both Mr. Hawley and the coachman, who usually takes the observations, were away at the time of my visit. The thermometer screen needed painting, and the legs renewing. The thermometers required rearranging in the screen. The tubes of the maximum and minimum had slipped down. These I readjusted.

LANCASTER, *August 30th.*—The instruments are placed in the Williamson Park, which was formerly moor land, and had been used as a quarry. The ground is consequently irregular, but the instruments are placed on the highest points. The thermometer screen required to be painted white and also to be raised, as the bulbs of the thermometers were only 3ft. 4 ins. above the ground. The tube of the maximum had slipped down 1°. The sunshine recorder is mounted on the roof of the Greg Observatory. The observations are made by the Curator of the observatory.

LLANDUDNO, *July 28th.*—All the thermometers were in good order except the minimum, which had 0°·5 of spirit at the top of the tube. I recommended that a cover be placed over the water receptacle. The sunshine recorder on the pier was somewhat out of focus. This I readjusted. The hills on the west cut off the sun in the evening, the highest point making an angle of 11°.

LINCOLN, *September 6th.*—There was no change in the thermometers. I recommended that a cover be placed over the water receptacle. The electrical thermometer was in good order. The screen on the tower required painting.

LOWESTOFT, *July 19th.*—There was no change in the thermometers. The tube of the maximum had slipped down. This I readjusted. The mercury in the maximum thermometer had a tendency to run up 2° or 3°. I called attention to this, and requested that the thermometer might be hung with the bulb a little lower.

MACCLESFIELD, *September 1st.*—The thermometers were all correct except the wet bulb, which had gone up 0°·1. One of the hinges of the door of the screen was broken and needed repairing.

NORTHWICH, *July 26th.*—The thermometers required to be rearranged and the screen painted. The lower part of the tubes of the dry and wet-bulb thermometers not being readable, owing to the piece of wood across them, I had this cut so that the tubes are now quite clear. The minimum had 0°·6 of spirit up the tube.

RAVENSTHORPE, *August 2nd.*—The dry and wet-bulb thermometers had gone up 0°·2. I recommended that the minimum be set horizontal and fixed tighter, to prevent vibration, and also that a cover be put over the water receptacle. A board with holes has been placed at the back of the stand, and is painted white.

ROTHBURY, *August 19th.*—The wet-bulb thermometer was not working properly, as the muslin was out of order. I altered the position of the maximum and minimum, and also put on fresh back-plates with slots. As there

was a piece of wood across the tubes of the dry and wet-bulb thermometers at about 25°, I recommended that this should be cut away, so that the column of mercury might be seen entire.

ROUNTON, *August 18th.*—The instruments were in good order, except the black-bulb maximum *in vacuo*, which had lost its index. As the wooden stick carrying the earth thermometer was rotting away, I recommended that it be bound round with wire. The observer was requested to give special attention to the wet-bulb thermometer during frost.

SCALEBY, *August 26th.*—The muslin on the wet-bulb was dry, and had not been kept in good order. The tubes of the dry and wet thermometers being loose, I put on fresh brass loops and screws. The screen required painting.

SCARBOROUGH, *July 12th.*—The observations are now taken by Dr. Monk, the Medical Officer of Health. The instruments are placed in a small garden with a very confined exposure. It is the only place available without going to such a distance that the instruments would not be under the supervision of the observer. The garden is about 200 feet east of Mr. Robinson's (the former observer), and is on the same level. The rain gauge is somewhat sheltered on the north-east by a tree which makes a considerable angle. I recommended that some branches of the tree be lopped. The screen required painting, and the thermometers rearranging.

SEATHWAITE, *August 28th.*—There was no change in the thermometers. I altered the position of the maximum and put on new back-plates. The amount of cloud appeared to be over estimated.

SOMERLEYTON, *July 19th.*—The instruments were all in good order, except the minimum, which had gone down 0°·5. As the Rev. C. J. Steward had two earth thermometers at 4 feet, one in a drain pipe and the other in an iron pipe, I suggested that the former should be put at 1 foot.

SOUTHWELL, *September 5th.*—All the thermometers were correct except the earth thermometer which had gone up 0°·1. The glass ball of the sunshine recorder was not quite in the centre of the frame. This I readjusted. The traces show that the sunshine has not been recorded in the morning before 5 a.m., while in the evening it has been recorded up to 8 p.m., and on June 9th, 1892, up to 8.5 p.m.

SUTTON COLDFIELD, *August 1st.*—The instruments have been moved to a site about 100 feet south of their former position. They are somewhat close to two ponds of water. The observations since January 1st have been taken only once a day, viz. at 9 a.m., instead of twice a day, viz. at 9 a.m. and 9 p.m., as formerly. I recommended that a cover should be put over the water receptacle. The screen required painting.

THORESBY (North), *July 14th.*—The instruments are placed in a paddock between the Rectory and the Church, and are well exposed. The ground is flat from the sea to the Wolds. North Thoresby is about 5 miles from the sea, and 2 miles from the Wolds. There was no change in the thermometers, which are those which the Rev. H. Garrett had formerly at Southampton. The muslin on the wet bulb was dry, the cotton not conducting properly. I recommended that a cover be placed over the water receptacle.

THURLOW, *September 27th.*—The muslin on the wet-bulb was dry, the cotton not conducting properly. I altered the position of the screws of the maximum thermometer as the mercury was liable to run up the tube. I recommended that the thermometers should be read to tenths instead of to whole degrees, and also that more attention should be given to the wet bulb.

USHAW, *August 18th.*—The thermometer screen required painting and strengthening. A new rain gauge was necessary as the existing one was completely worn out. I recommended that a cover be placed over the water receptacle.

WAKEFIELD, *July 10th.*—There was no change in the thermometers. The screen required painting and the thermometers re-arranging. As the water receptacle was liable to be burst in frost, I recommended that a fresh one with a cover be obtained. The observations will in future be entered direct in the original observation book instead of on loose pieces of paper.

WINDERMERE, *August 29th.*—The instruments are placed in a small yard or garden, the exposure is consequently very confined. The rain gauge is placed on a wall 6 feet above the ground. Mr. Mackereth has had, however, three gauges placed in open situations, and always found that they collected the same amount as that on the wall.

WORTHING, *October 11th.*—I called on Mr. G. B. Collet at Shelley House and found him willing to carry on the observations so ably taken by the late Mr. W. J. Harris during the past 26 years. I selected a site for the instruments, which would be put in position before the end of the month.

WRYDE, *July 17th.*—There was no alteration in the thermometers, but I found that the maximum read too high by the mercury having a tendency to run up the tube. This I remedied by lowering the bulb and also by tightening the screws to prevent vibration. The tube of the maximum thermometer had slipped down about a degree. This I readjusted.

APPENDIX IV.

OBITUARY NOTICES.

HENRY FRANCIS BLANFORD, who died after a protracted illness on January 23rd, 1893, was born in 1834, in Bouverie Street, in the house now the offices of the *Daily News*. He was one of the students of the Royal School of Mines at its opening in 1851, and like other meteorologists, such as the late Prof. Buys Ballot, Prof. Mohn, and Mr. Scott, his earliest work was Geological. He studied at Freiberg for a year, and joined the Geological Survey of India in 1855. He had to leave that service in 1862, as his health would not stand the exposure to climate involved in geological exploration, but in those seven years he did work, the permanent value of which has been thoroughly recognised.

In 1862 he joined the Educational Department, and was soon appointed Professor of Physics in the Presidency College of Calcutta. He began to

devote himself to meteorological inquiries, and when the Calcutta Cyclone of October 1864 forced on the notice of the Government the desirability of organising storm warnings, Mr. Blanford was appointed Honorary Secretary to the Meteorological Committee, charged with the arrangements for a tentative scheme of this nature. Soon after he was formally appointed Meteorological Reporter to the Government of Bengal, and in 1875 he was finally constituted Director of the Central Office, or Meteorological Reporter to the Government of India. In March 1887 he took furlough for 21 months, and on its expiration he retired.

His *Indian Meteorologist's Vade Mecum*, published in 1877, is the best book of Instructions for all tropical countries, and in his *Weather and Climates of India*, published in 1889, he gives the results of his life's work in the investigation of the Climate of the Indian Peninsula.

The *Indian Meteorological Memoirs* contain numerous papers from his pen, and his name also appears in the Royal Society's *Proceedings*, and in the *Philosophical Transactions*, as well as in the *Proceedings of the Asiatic Society of Bengal*. He became F.R.S. in 1880, and was an honorary member of several foreign Meteorological Societies.

He was elected a Fellow of this Society on November 20th, 1878, and served on the Council from 1888 to 1891. R. H. S.

Sir Andrew Clark, Bart., M.D., LL.D., F.R.S., was born on October 28th, 1826, at Aberdeen, and educated at the Universities of Aberdeen and Edinburgh, where he highly distinguished himself. He graduated M.D. at Aberdeen in 1854, and became a Surgeon in the Royal Navy and later on Pathologist to the Royal Naval Hospital at Haslar.

However, it was not until he came to the Metropolis, and was appointed a member of the Medical Staff of the London Hospital, that he made his mark. By long and patient study of morbid anatomy, he became first a great pathological teacher, and, connecting this with bedside experience, a distinguished clinical lecturer, attracting crowds of admiring students and practitioners. He subsequently became involved in a large consulting practice, which he retained up to his death.

Sir Andrew Clark was President of several of the Medical Societies, including the Medical, the Clinical, and Hunterian, and at the time of his death presided over the Royal Medico-Chirurgical Society, in whose debates he took a warm interest. But of late years, his principal public work was in connection with the Royal College of Physicians, in which he held the various offices of Examiner, Croonian and Lumleian Lecturer, and eventually President, which office he held up to the last with the greatest dignity and ability, and with the utmost devotion to the interests of the College and of the Medical Profession. He was attacked with apoplexy while seeing his patients as usual, and died, as he would have desired, at his post, on November 6th, 1893, aged 67.

His chief characteristics were, first, his untiring energy and extraordinary power of work; secondly, his great sympathy with suffering, and ready

resource in its alleviation; thirdly, his eloquence, both of speech and of pen, which enabled him to elucidate most complex questions, to champion with success many a good cause, and last, but not least, to give his medical directions in such clear language that they could not be misunderstood.

Sir Andrew Clark's funeral service, November 11th, 1893, was held in Westminster Abbey, and largely attended by his friends and patients, among them Mr. Gladstone, who was a pall bearer. He was buried at Essendon, in Hertfordshire.

He was elected a Fellow of this Society on April 20th, 1892, and always expressed much interest in Climatology. C. T. W.

DANIEL COLLADON was born at Geneva, Switzerland, in the year 1802, and educated in that town. In early life he took much interest in Physical Science, and evinced considerable aptitude in experimental inquiry in Natural Philosophy. At 28 years of age he had to conform to the law of the country and undergo military training, which he appears to have rather enjoyed. We next find him engaged for two years attending lectures in Philosophical Science at the Geneva Academy; during that time his inquiring turn of mind set him to work on various topics, and in 1825 he published a paper together with Dr. Prevost, of Geneva, on a phenomenon described by Arago concerning the influence of metallic plates on magnets. Arago was then the centre of the physical world on the Continent, and it is not surprising that Colladon should have felt a great desire to make his acquaintance. With this object he proceeded to Paris in company with Sturm, who subsequently distinguished himself greatly as a physicist and mathematician.

On his arrival in Paris, Colladon found that the great topic of interest was the construction of a passage under the Thames, with which the engineer, Mr. Brunel, was actively engaged; the tunnel had then reached half way under the river, when suddenly a violent irruption of water took place, and the works had to be interrupted. Colladon then suggested to Mons. de Lessert, who had subscribed largely to the funds required for the undertaking, that it might have added to the safety of the boring to undertake the work under compressed air, one or two atmospheres being probably sufficient, supposing the tunnel to be closed by an iron shutter and the air compressed within it by means of powerful pumps. Colladon put his suggestion in writing, and the letter was forwarded to Brunel, but no answer was ever returned to it. It seems, however, that on a later occasion Brunel recollected Colladon's suggestion.

Colladon while in Paris became acquainted with Arago, Ampère, and Humboldt, and was naturally led to investigate the subject of electricity. He succeeded in causing a deviation of the magnet through the agency of an electric friction machine, and up to that time such an effect was only known to be produced by a voltaic pile. Colladon's attention was next turned to atmospheric electricity. A metallic point was fixed to the end of a long rod, and this he erected on the Observatory of the "College de France,"

and placed alongside of the lightning conductor, which it exceeded in height by more than one metre. The point was enclosed in a glass tube and two conductors, isolated by means of silk let down from the end of the point into a room where they were fixed to a galvanometer Colladon himself had invented. A storm occurring at the time, no sooner was the apparatus mounted than the needle of the galvanometer was deviated in such a way as to show the electricity to be negative. Two days later another more violent storm occurred, and during 20 minutes the direction of the currents changed two or three times. Wishing to break the conductor at the moment of the maximum deviation of the galvanometer, Colladon received a succession of powerful spark discharges.

Shortly afterwards Colladon entertained the idea of determining the rate of transmission of sound through water, and returned to Geneva to carry out his experiments in the lake. This he did at night by placing a person at a distance of 14,237 metres, while he himself was in a boat; this person fired a rocket, and at the same moment struck a bell with a hammer, the bell being immersed in the lake; the sound was perceived through a long tube bent at its immersed end, and widened somewhat like a trumpet; the wide immersed extremity of tube was closed by a diaphragm. He observed the time required for the transmission of the sound with a watch. A great number of experiments were made, and finally Colladon found for the transmission of sound through water a speed of 1,435 metres per second.

Atmospheric electricity was evidently a favourite study for Colladon, and in 1826 and 1827 he made some very interesting experiments near Geneva, selecting two stations at a difference of altitude of 780 metres. These observations confirmed the accepted opinion that in fine weather the atmosphere in plains, except where under the influence of trees, smoke or overhanging buildings, is electrified positively at a few metres above the earth.

About this time Colladon, who had given much attention to steam engines, became actively engaged as a Consulting Engineer; we now pass over a portion of his career, mostly devoted to engineering, and coming to his researches more strictly meteorological, we find him busy with observations on hail.

He was led to his theory of the formation of hail by a phenomenon he remarked in waterfalls, where he had observed an upward current of air to be produced by the falling water, this current causing an upward motion of the water particles on the outer layer of the fall. According to Colladon's theory, the production of hail is owing to the formation of a vertical descending air current produced by a sudden and heavy shower; this current leaves behind a vacuum, or a considerable fall of pressure, mostly located in the cloud from which originated both the shower and the hail. Thus, in that cloud there is a permanent indraught of air as long as the storm lasts. This indraft brings to the cloud cold and dry air from above, as well as air from below, the upper air being strongly electrified and possibly mixed with acicular ice crystals or drops of water in the process of freezing. The draught thus produced would divide the cloud into a number of portions differently

electrified, and consequently the hailstones would be attracted and repelled by these separated cloud masses, increasing in size all the while.

This view on the origin of hail led Colladon to inquire into the formation of tornadoes, and he contended that tornadoes were not all descending, as was thought to be the case according to Fay's law, but that they are sometimes ascending. He founded this view on numerous observations of whirlwinds, in which dust and various terrestrial objects were lifted into the air by a tornado and deposited at some distance from the spot over which the tornado had passed. One of the most interesting of those observations relates to a tornado which passed over the town of Geneva, and swept within its sphere of action a quantity of clothes hung up to dry; the circular movements of these clothes mixed with masses of dust indicated clearly the gyration of a column of air 8 metres in diameter; he estimated the height of this tornado at 600 metres.

The effects of lightning on trees and plants were subjects of great interest to Colladon, and he examined these effects closely on poplars, oaks, elms, cherry trees, pear trees, firs, cedars, horse chestnuts, walnut trees, plane trees, and vines. With reference to poplar trees he was surprised to find that in some instances no signs of being struck by lightning could be seen on the upper four-fifths of the tree. He noticed in one case two longitudinal wounds in the bark, in the middle of which there appeared a longitudinal slit 1 or 2 millimetres in thickness, where the blade of a knife could be inserted to a depth of 3 or 4 centimetres; along those slits two well defined bands or lips were visible 4 or 5 millimetres in breadth; these bands were coloured light brown, like wood dried in an oven, but the most remarkable feature was the occurrence of seven perfectly round spots 8 to 10 millimetres in diameter, disposed along the slit at a mean distance of 1·80 metre above the soil.

He described as follows the lightning spots on a fir tree:—"On the inferior portion of the trunk, at a height of 2·60 metres, ten circular spots could be seen placed along a fissure in the wood. These circles or spots vary in diameter from 3 to 5 centimetres; they are situated at the surface of the young wood, their colour is dark brown, slightly darker near their circumference; they have a depression at the centre from 1 to 2½ millimetres in depth. Those ten circles are traversed by the slit which intersects them either through their centre or at the sides." Summing up the subject of those spots, he remarks that he has observed them on eight different trees.

He finally observed the effects of lightning on vineyards. In vineyards struck by lightning he found that the damaged extent distinguished itself from the rest of the plantation by the presence of numberless spots on many of the leaves of a brick red colour. These spots were irregular, and covered a third, or perhaps half, the surface of the leaves. Other irregular spots were also observed, exceeding the former in number and coloured dark blackish green. He leaves it an open question whether the dark green spots become or not the seat of the brick-red coloration; according to the manager of a vineyard under Colladon's observation, the dark green spots

were the primary effects of the lightning, and after some days they assumed the brick-red colour. Colladon had opportunities for the examination of 17 different vineyards struck by lightning; in nearly every case a circular or elliptic region from 8 to 18 metres in diameter had suffered.

Colladon was greatly distinguished as an Engineer, and perhaps his most remarkable invention was his perforating machine, worked by compressed air, which was successfully used in the Mont Cenis Tunnel. He was also Professor of Mechanics at the École Centrale of Paris and Academy of Geneva. The author of this biographical notice had the pleasure of Colladon's personal acquaintance, and will ever recollect his kindly and genial welcome.

Daniel Colladon died on June 30th, 1893, and was therefore in his 91st year of his age, his active mind being at work to the very last. He wrote an autobiographical volume, from which the present notice of his life has been extracted.

He was elected an Honorary Member of this Society on May 18th, 1888.

W. M.

Professor Henri Marié Davy, who died at Clamecy, Nièvre, in July at the age of 72 years, had been elected a Foreign Member of this Society on April 17th, 1878. He took his Doctor's degrees in Medicine, Physical Sciences and Mathematics in Paris, in 1840, and he successively held Professorships of Physics at various provincial Colleges in France. Rouen was one of these. Soon after the organisation of the Meteorological Service at the Observatoire de Paris, he was appointed by Leverrier to superintend that department of the observatory work. In 1866, he brought out his Meteorological work *Les Mouvements de l'Atmosphère et les Variations du Temps*, a book which reached a second edition in 1877.

Differences of opinion between Professor Marié Davy and his chief severed the relations between them, and he left the Observatory some time before 1870. After the war, in 1873, he came back to Paris as Director of the Montsouris Observatory, an establishment in relation with the Paris Municipality, where, as is well known, not only Meteorology, but the microscopic examination of air and rain and Terrestrial Magnetism are prosecuted. He held that post until 1887.

Henry Edward Stanley, Earl of Derby, was born in July 1826. He was educated at Rugby, under Arnold, and at Cambridge, where, as a student of Trinity College, he gave promise of his future success in life. He obtained a first-class in the classical tripos, and also took honours in mathematics.

From 1848 to 1869, when he succeeded his still more celebrated father, the fourteenth Earl of Derby, he represented the borough of King's Lynn. He entered upon a long and eventful Ministerial career at the exceptionally early age of 26, his first office under the Crown being the not unimportant one of Under Secretary of the Colonies. Subsequently Lord Palmerston, anxious

to secure his support, placed the Colonial Secretaryship at his disposal. The offer, though declined, was a great compliment to the ability of a man not yet 40.

As a member of his father's second Cabinet, Lord Stanley, as he was then, had charge of the Bill transferring the government of India from the Company to the Queen, and the manner in which he piloted that historic measure through the House of Commons greatly increased his reputation. At a later period he twice filled the post of Secretary of State for Foreign Affairs, and more recently he was Secretary of State for the Colonies, a position he had occupied for a short time in earlier years.

Lord Derby was much sought after for Royal Commissions, where his practical knowledge, sound sense and clear judgment were of considerable advantage to the State. He served as a Member of the Royal Commission on Army Purchase (1856-7); of the Cambridge University Commission (1856-60); and of the Commission on the Organisation of the Indian Army (1858-9). He was Chairman of the Commission on the Sanitary State of the Indian Army (1859-61); of the Commission on Patents (1863-4); of the Commission on City Guilds (1881-2); and of the Commission on Market Rights and Tolls (1888-90).

Lord Derby was distinguished among politicians for the genuine interest he displayed in social questions, and this interest with him was not a thing of yesterday.

Not a few scientific or academic distinctions fell to his lot. Among the former may be mentioned his Fellowship of the Royal Society. His *alma mater* made him an LL.D., and Oxford gave him her degree of D.C.L. He was installed Lord Rector of Glasgow University in 1869, and Lord Rector of Edinburgh University in 1875. He succeeded the late Earl Granville as Chancellor of the University of London.

Though he never attempted anything so elaborate as his gifted predecessor's translation of Homer's Iliad, he was not destitute of literary skill. Among the pamphlets he wrote was one on the *Overland Route to the Pacific*, and another on Church Rates. He also published, as a young man, a readable *brochure*, entitled *Six Weeks in South America*.

Of late he had withdrawn very largely from active politics. In many other spheres he will be much missed.

Lord Derby died on April 20th, 1893.

He was elected a Fellow of this Society on March 19th, 1879.

Lord Ebury was born on April 24th, 1801. He was the third son of the second Earl and first Marquess of Westminster, his eldest brother subsequently succeeding to the family dignities and his second brother becoming Earl of Wilton. Lord Ebury was consequently uncle to the present Duke of Westminster.

Educated at Westminster and at Christ Church, he entered the House of Commons as Whig member for Shaftesbury in 1822, a seat which he held for four years. From 1826 to 1847 he represented the city of Chester, and

from 1847 to 1857 the county of Middlesex. On Lord Grey becoming Prime Minister in the autumn of 1830, Lord Ebury, then Lord Robert Grosvenor, became Comptroller of the Household, and in Lord John Russell's Ministry of 1846 he resumed office as Treasurer of the Household and Groom of the Stole to the Prince Consort. Eleven years later he received, on the recommendation of Lord Palmerston, the honour of a peerage, taking his seat in the Upper House as Lord Ebury. At the time of his death, on November 18th, 1893, he was the oldest member of the House of Lords. He was also far the oldest Privy Councillor, having been a member of that body some years when the Queen came to the throne.

As a politician Lord Ebury filled no considerable space in the events of recent years. He was much more concerned with matters of philanthropic and religious interest, in which he was frequently associated with the late Lord Shaftesbury.

Lord Ebury always took a great interest in Meteorology, and in 1838 served on the Council of the original Meteorological Society of London. In the following year he was elected President, and continued to hold that office until the dissolution of the Society on August 14th, 1850. Lord Ebury joined the newly formed British (now the Royal) Meteorological Society on May 7th, 1850, and was then elected Vice President, a position which he occupied till May 27th, 1856.

William John Harris was educated at the Merchant Taylors' School, and afterwards proceeded to St. Bartholomew's Hospital for the study of medicine. He joined his father in practice at Worthing, and ultimately became one of the leading medical men of that town.

He became M.R.C.S. in 1859, and was a member of several Medical Societies. He was President of the South-Eastern Branch of the British Medical Association, 1886-7.

Mr. Harris took a prominent part in all the social, philanthropic and educational movements in Worthing. He was a member and for several years Chairman of the Local Board.

He suffered much from paralysis during the last few years of his life, and retired from practice about a year before his death. He died from typhoid fever on August 28th, 1893, aged 55 years.

Mr. Harris was greatly devoted to Meteorology, and took observations at Worthing from 1867 to the time of his death.

He was elected a Fellow of this Society on November 20th, 1867, and served on the Council for 1875.

Thomas Hawksley was born at Nottingham in 1807. He was educated as an architect and surveyor, but, having an inclination for mechanical pursuits, he studied diligently the sciences necessary to enable him to practise as a civil engineer, and with such success that in 1830 he undertook the construction of new waterworks for his native town. The knowledge and skill he exhibited in these works led to more practice in other districts, and

in 1852 he removed his offices to London, where before long he took the highest rank in that branch of engineering having to do with water and gas supply, and with drainage and hydraulic works generally.

Mr. Hawksley was accustomed to say that he had constructed above 150 waterworks, many of the largest character; and that there were no important towns in Great Britain, and indeed very few great cities in the civilised world, in regard to which he had not been professionally consulted in some way or other. He is especially celebrated for having been the first to suggest and to carry into practice the system of "constant service" in water supply, which combined the most free and ample provision of water with the almost perfect repression of waste, and with greatly improved sanitary conditions. The introduction of the system involved many difficulties and much opposition; but he always spoke of his success in it with great satisfaction and pride.

It must not be supposed that municipal engineering in the days of Mr. Hawksley's early practice meant simply building and mechanical operations. It involved often grave and novel considerations, and it was his merit to bring to bear upon them accurate scientific knowledge and careful study. The lucid and skilful manner in which he was in the habit of applying scientific principles to his professional practice was well known to engineers generally: "Mr. Hawksley's formulæ," "Mr. Hawksley's data," "Mr. Hawksley's general results," and so on, were continually adopted as familiar guides by his professional brethren, and were quoted as authorities against which there could be no appeal.

On one occasion he had to advise on the drainage of one of the largest towns in the kingdom, and a question arose involving some artificial hydraulic conditions of much greater magnitude than usual. Doubts were expressed as to the feasibility of his scheme; but Mr. Hawksley had a strong impression that the ordinary rules, based on comparatively small experiments, did not apply. He accordingly examined the question thoroughly, bringing to his aid certain recent hydraulic researches by eminent French mathematicians; and, with the help of the writer of this notice, he succeeded in showing the practicability of the plan by an amount of scientific evidence which, while it was perfectly new, was absolutely incontrovertible.

Mr. Hawksley was President of the Institution of Civil Engineers for the years 1872 and 1873, and of the Institution of Mechanical Engineers in 1876 and 1877.

In 1876 he was elected President of the National Association of Social Science, holding their meeting at Liverpool, when he gave an address especially remarkable for its happy application of statistics to sanitation. He was a clever and lucid writer, and his keen appreciation of scientific reasoning gave weight to his opinions.

He was elected a Fellow of the Royal Society on June 6th, 1878, as being "especially distinguished for the application of Science to Hydraulic Engineering."

Mr. Hawksley was blessed with a constitution which prolonged his life and energy much beyond the ordinary lot of man. In the beginning of September 1893, 63 years after his appointment as engineer to the Nottingham Waterworks, he undertook one of his customary tours of inspection of his works in progress in distant parts of England; but a fortnight afterwards he was attacked by a sudden and formidable disease, which his aged frame was not able to resist, and he died at his residence at Kensington on September 23rd.

He was elected a Fellow of this Society on January 22nd, 1866.

W. P.

George Mathews Whipple was born at Teddington in 1843, where his father at that time held the position of Master of the Public School. He was educated at the Grammar School at Kingston, and at the age of 15, in 1858, he was first engaged as a boy at the Kew Observatory, at which establishment he was connected for the rest of his life. He became Magnetic Assistant in 1862, and in 1876 was appointed Superintendent.

In discharge of his various duties in connection with that Observatory, Mr. Whipple became identified with the progress of most of the researches carried on there during the long space of 36 years. Among these we may specially mention the pendulum experiments made for the purposes of the Great Trigonometrical Survey of India, and the anemometer experiments at first commenced under Mr. Jeffery at the Crystal Palace, and later carried on with Mr. W. H. Dines at Horsham, the results of which have appeared in the Reports of the Wind Force Committee in the *Quarterly Journal*.

Mr. Whipple was the author of the magnetic portion of the Krakatoa Report.

He communicated several papers to the *Proceedings of the Royal Society*, and our own *Quarterly Journal* contains no less than 22 papers bearing his name either as sole or joint author.

He served on the Council from 1876 to 1887, for two years acting as Foreign Secretary. He was a B.Sc. of the London University, a Fellow of the Royal Astronomical Society, and an active Member of the Physical Society.

He died on February 8th, 1893, after a long and very painful illness, at the age of 50 years, and all who knew him mourn his loss as a thoroughly conscientious worker, a most courteous official, and a warm friend.

He was elected a Fellow of this Society on April 18th, 1874.

R. H. S.

APPENDIX V.

BOOKS PURCHASED DURING THE YEAR 1893.

Anderson, A. C.—The Dominion at the West, a brief description of the province of British Columbia, its climate and resources. 8°. (1872.)

B[urton], R.—The surprizing miracles of nature and art. 24mo. (1683.)

COLLECTION of meteorological cuttings from the *Gentleman's Magazine*, *London Magazine*, and *Universal Magazine*, 1735 to 1753.

DAVY, J.—Notes and observations on the Ionian Islands and Malta. Two vols. 8°. (1842.)

ELIE, J. A. van.—Meteorologische Waarnemingen, gedaan voor de Maatschappij Felix Meritis, te Amsterdam. Van 1° Dec. 1849-1°Dec. 1852. F°. (1850-2.)

FRANÇOIS, R.—Essay des merveilles de nature, et des plus nobles artifices. Neufième édition. 8°. (1644.)

FULLER, A.—South Africa as a health resort. Second edition. 8°. (1889.)

GOODISSON, W.—A historical and topographical essay upon the islands of Corfù, Leucadia, Cephalonia, Ithaca, and Zante. 8°. (1822.)

HALL, C. R.—Torquay in its medical aspect as a resort for pulmonary invalids. 12°. (1857.)

HELLMANN, G.—Neudrucke von Schriften und Karten über Meteorologie und Erdmagnetismus. No. 1. L. Reynman. Wetterbüchlein von wahrer Erkenntniss des Wetters. 1510. Facsimiledruck mit einer Einleitung. 4°. (1893.)

————.—No. 2. Blaise Pascal. Récit de la Grande Expérience de l'Équilibre des Liqueurs. Paris, 1648. Facsimiledruck mit einer Einleitung. 4° (1893.)

HILLARY, W. Observations on the changes of the air, and the concomitant epidemical diseases in the Island of Barbadoes. 8°. (1759.)

HUGHES, S.—A treatise on Waterworks. New edition. 12°. (1875.)

HUMBOLDT, A. de—Asie Centrale. 3 vols. 8°. (1843.)

HUXLEY, T. H.—Physiography. 8°. (1890.)

INDEX GEOGRAPHICUS; compiled specially with reference to Keith Johnston's Royal Atlas. 8°. (1864.)

KEBBELL, W.—The climate of Brighton. 12°. (1859.)

L'ASTRONOMIE, 1893. 8°. (1893.)

LAWSON, H.—A paper on the arrangement of an observatory for practical Astronomy and Meteorology. 8°. (1844.)

[M ————, J. R.]—A companion to the Anglo Chinese Kalendar, 1832. 8°. (1832.)

MACNAB, J.—Catechism of the Law of Storms for the use of sea officers. New and enlarged edition. 8°. (1893.)

MADDEN, T. M.—On change of Climate. 8°. (1864.)

MATHER, I.—An essay for the recording of illustrious Providences. 8°. (Library of Old Authors. Reprint.)

METCALFE, S. L.—Caloric. In 2 vols. 8°. (1848.)

METEOROLOGICAL REGISTER kept in Sussex (probably at or near Petworth), June 1772 to June 1778. F°. (MS.)

NEW BRUNSWICK, ST. JOHN, BOARD OF TRADE.—Report of the Special Committee on the Bay of Fundy and Harbor of St. John, N.B. 8°. (1887.)

OFFICIAL YEAR BOOK OF THE SCIENTIFIC AND LEARNED SOCIETIES of Great Britain and Ireland, 1893. 8°. (1893.)

PEEL, W.—A ride through the Nubian Desert. 8°. (1852.)

SMOLLETT, T.—Miscellaneous works. Vol. V. 8°. (1800.) [Contains a register of the weather at Nice, Nov. 1763 to March 1765.]

VINCE, S.—An account of a very remarkable Waterspout at Ramsgate in the afternoon of July 16, 1810. 4°. (1815.)

WALDO, F.—Modern Meteorology. 8°. (1893.)

WHISTLECRAFT, O.—Meteorological Journals kept at Thwaite, 1827-1892. 24 vols. (MS.)

APPENDIX VI.

DONATIONS RECEIVED DURING THE YEAR 1893.

Presented by Societies, Institutions, &c.

ADELAIDE, OBSERVATORY.—Meteorological Observations made at the Adelaide Observatory and other places in South Australia and the Northern Territory, 1884-5 and 1890.—Rainfall in South Australia and the Northern Territory, Aug. 1892 to July 1893.

ALLAHABAD, METEOROLOGICAL OFFICE.—Annual statement of Rainfall in the North-Western Provinces and Oudh, 1892.

BARBADOES, COLONIAL SECRETARY'S OFFICE.—Returns of Rainfall in Barbadoes, Dec. 12, 1892, to Dec. 3, 1893.

BATAVIA, MAGNETICAL AND METEOROLOGICAL OBSERVATORY.—Observations, 1891.—Rainfall in the East Indian Archipelago, 1891.

BERLIN, DEUTSCHE METEOROLOGISCHE GESELLSCHAFT.—Meteorologische Zeitschrift, Dec. 1892 to Nov. 1893.

BERLIN, GESELLSCHAFT FÜR ERDKUNDE.—Verhandlungen, Band XIX. No. 9 to Band XX. No. 7.—Zeitschrift, Band XXVII. No. 4 to Band XXVIII. No. 3.

BERLIN, KÖN. PREUSS. METEOROLOGISCHES INSTITUT.—Bericht über die Thätigkeit, 1891 and 1892.—Ergebnisse der Beobachtungen an den Stationen II. und III. Ordnung 1893.—Ergebnisse der meteorologischen Beobachtungen, 1892, Heft 2.—Ergebnisse der Niederschlags-Beobachtungen, 1891.

BOMBAY, METEOROLOGICAL OFFICE.—Brief Sketch of the Meteorology of the Bombay Presidency, 1891-3.

BOSTON (MASS.), BLUE HILL OBSERVATORY.—Measurements of cloud heights and velocities; by H. H. Clayton and S. P. Fergusson.—Observations, 1891.

BOSTON (Mass.), NEW ENGLAND WEATHER SERVICE.—Bulletin, Dec. 1892 to Nov. 1893.

BREMEN, METEOROLOGISCHE STATION.—Ergebnisse der meteorologischen Beobachtungen, 1891.

BRISBANE, CHIEF WEATHER BUREAU.—Meteorological Report, 1888-91.—Notes on some of the more common diseases in Queensland in relation to atmospheric conditions, 1887-91, by Dr. D. Hardie.—Summaries of rainfall in Queensland, Oct. 1891 to Sept. 1892.

BRISBANE, GENERAL REGISTER OFFICE.—Annual Report by the Registrar General of Queensland, 1892.—Report on the vital statistics, Nov. 1892 to Sept. 1893.

BRISBANE, QUEENSLAND BRANCH OF THE ROYAL GEOGRAPHICAL SOCIETY OF AUSTRALASIA.—Proceedings and Transactions, Vol. VIII., 1892-3.

BRUSSELS, ACADÉMIE ROYALE.—Annuaire, 1892-3. Bulletins, Tomes XXII.-XXV., 1891-3.

BRUSSELS, INSTITUT NATIONAL DE GÉOGRAPHIE.—Bulletin Météorologique, Dec. 1892 to Nov. 1893.

BRUSSELS, OBSERVATOIRE ROYAL DE BELGIQUE.—Annales. Observations météorologiques d'Uccle, June to Dec. 1892.—Annuaire, 1893.

BUDAPEST, K. UNG. CENTRAL-ANSTALT FÜR METEOROLOGIE UND ERDMAGNETISMUS.—Jahrbuch, 1890.

BUKHAREST, INSTITUT MÉTÉOROLOGIQUE DE ROUMANIE.—Annales, 1890.—Buletinul Observatiunilor Meteorologice din Romania, Aug. and Dec. 1892, and Jan. to Nov. 1893.—Resumé des Observations Météorologiques de Bukharest (Filaret) pour 1890, et pour la période de 1885-90, par S. C. Hepites.

CAIRO, SOCIÉTÉ KHÉDIVIALE DE GÉOGRAPHIE.—Bulletin, IIIe Série, Nos. 11 and 12.

CALCUTTA, METEOROLOGICAL DEPARTMENT OF THE GOVERNMENT OF INDIA.—Cyclone Memoirs, No. 5. Account of the three cyclones in the Bay of Bengal and Arabian Sea during Nov. 1891, by J. Eliot.—Daily Weather Charts of the Indian Monsoon Area, Jan. 1 to July 17, 1893.—Indian Daily Weather Reports, Dec. 5, 1892, to Dec. 3, 1893.—Indian Meteorological Memoirs, Vol. IV. part 8, and Vol. V. parts 2 and 3.—Memorandum on the snowfall in the mountain districts bordering Northern India and the abnormal features of the weather in India during the past five months [Jan. to May], with a forecast of the probable character of the South-west Monsoon rains of 1893.—Monthly Weather Review, June 1892 to July 1893.—Rainfall data of India, 1891 and 1892.—Registers of original observations, reduced and corrected, June 1892 to July 1893.—Reports on the Administration of the Meteorological Department of the Government of India, 1891-3.—Report on Calcutta Cyclone of Oct. 5, 1864; by Lieut.-Col. J. E. Gastrell and H. F. Blanford.

CAPE TOWN, METEOROLOGICAL COMMISSION.—Report, 1892.

CHEMNITZ, KÖNIGL. SÄCHSISCHES METEOROLOGISCHES INSTITUT.—Das Klima des Königreiches Sachsen. Hefte 1 and 2.—Ergebnisse der meteorologischen Beobachtungen, 1892, I. Hälfte.—Jahrbuch, 1891, part 3, and 1892, part 3.

CHRISTIANIA, NORSKE METEOROLOGISKE INSTITUT.—Jahrbuch, 1891.—Nedborhoid·n i Norge, beregnet efter observationer 1867 til 1891 af det Meteorologiske Institut.

COLOMBO, SURVEYOR GENERAL'S OFFICE.—Report on the Meteorology of Ceylon, 1892.

COPENHAGEN, DANSKE METEOROLOGISKE INSTITUT.—Bulletin Météorologique du Nord. Dec. 1892 to Oct. 1893.—Meteorologisk Aarbog, 1890, part 2, and 1892, part 1.

CORDOBA, ACADEMIA NACIONAL DE CIENCIAS.—Boletin, Tomo X., part 4, and Tomo XI., part 4.

CRACOW, K. K. STERNWARTE.—Meteorologische Beobachtungen, June 1892 to July 1893.

CROYDON, MICROSCOPICAL AND NATURAL HISTORY CLUB.—Daily Rainfall in the Croydon district, Dec. 1892 to Oct. 1893.—Report of the Meteorological Sub-Committee for 1892.

DORPAT, OBSERVATORIUM.—Meteorologische Beobachtungen, 1892.

DUBLIN, GENERAL REGISTER OFFICE.—Annual Report of the Registrar-General (Ireland), 1891.—Weekly Returns of Births and Deaths, 1893.

DUBLIN, ROYAL IRISH ACADEMY.—Proceedings, Third Series, Vol. II. Nos. 3-5, and Vol. III. No. 1.—Transactions, Vol. XXX. parts 1-10.

EDINBURGH, FISHERY BOARD FOR SCOTLAND.—Annual Report, 1892, part 3. Scientific Investigations.

EDINBURGH, GENERAL REGISTER OFFICE.—Quarterly Returns of the Births, Marriages and Deaths registered in Scotland for the four quarters ending Sept. 30, 1893.

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EDINBURGH, SCOTTISH METEOROLOGICAL SOCIETY.—Guide to Ben Nevis, with an account of the foundation and work of the Meteorological Observatory.—Journal. Third Series, No. 9.

FIUME, I. R. ACCADEMIA DI MARINA.—Meteorological Observations, June 1892 to June 1893.

GENEVA, SOCIÉTÉ DE GÉOGRAPHIE.—Le Globe, Tome XXXII.

GLASGOW, PHILOSOPHICAL SOCIETY.—Proceedings, Vol. XXIV., 1892-3.

GREENWICH, ROYAL OBSERVATORY.—Magnetical and Meteorological Observations, 1890. —Report of the Astronomer Royal to the Board of Visitors, 1893.

HAMBURG, DEUTSCHE SEEWARTE.—Aus dem Archiv, 1892.—Deutsche überseeische meteorologische Beobachtungen, Heft V.—Ergebnisse der meteorologischen Beobachtungen in Deutschland, 1891.—Wetterbericht, 1893.

HONG KONG, OBSERVATORY.—Observations and Researches, 1892.

KARLSRUHE, CENTRALBUREAU FÜR METEOROLOGIE UND HYDROGRAPHIE IM GROSSHERZOGTHUM BADEN.—Die Ergebnisse der meteorologischen Beobachtungen, 1892.—Niederschlagsbeobachtungen der meteorologischen Stationen im Grossherzogthum Baden, 1892, part 2.

KEW, OBSERVATORY.—Report of the Kew Committee, 1892.

KIEW, OBSERVATOIRE MÉTÉOROLOGIQUE DE L'UNIVERSITÉ.—Etude sur la couche de neige dans le Bassin du Dnièpre, Oct. 1892 to Jan. 1893.—Observations, 1892.

LEON, ESCUELA DE INSTRUCCION SECUNDARIA.—Resumen general de las observaciones meteorologicas, 1891.

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LONDON, COLONIAL OFFICE.—Annual Meteorological Report, Straits Settlements, 1892. —Annual Report of the Director of the Royal Alfred Observatory, Mauritius, 1891.—Frost in Hong Kong.—Observations and Researches at Hong Kong Observatory, 1892. —The cold wave of Jan. 1891 in Hong Kong. By S. B. J. Skertchly.

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LONDON, ROYAL ASTRONOMICAL SOCIETY.—Monthly Notices, Vol. LIII. No. 2, to Vol. LIV. No. 1.

LONDON, ROYAL BOTANIC SOCIETY.—Quarterly Record, Nos. 52 to 55.
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LONDON, SANITARY INSTITUTE.—Transactions, Vol. XIII. 1892.
LONDON, SOCIETY OF ARTS.—Journal, 1893.
MADRAS, METEOROLOGICAL OFFICE.—Hourly Meteorological Observations, Jan. 1856 to Feb. 1861.—Madras Weather Chart, Nov. 1 to 16, 1893.
MADRID, OBSERVATORIO.—Observaciones meteorológicas, 1890-1.—Resumen de las observaciones meteorológicas efectuadas en la Peninsula, 1890.
MADRID, SOCIEDAD GEOGRAFICA.—Boletin, Tomo XXXIII. No. 4 to Tomo XXXV. No. 3.
MAGDEBURG, WETTERWARTE DER MAGDEBURGISCHEN ZEITUNG.—Jahrbuch, 1891.
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MELBOURNE, OBSERVATORY.—Record of Results of observations in Meteorology, Terrestrial Magnetism, &c., July to Dec. 1892.
MEXICO, CENTRAL METEOROLOGICAL OBSERVATORY.—Anales del Ministerio de Fomento de la Republica Mexicano, Tomo IX.—Brief historical sketch of the meteorology in the Mexican Republic.—El Clima de la Ciudad de México. Por M. Bárcena.—General summary of the meteorological observations taken in several localities of the United States of Mexico.—Resumen del año de 1892.—Servicio Pluviometrico Resumen del año de 1892.—Summary of 16 years' observations (1877-1892).
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MICHIGAN, STATE BOARD OF HEALTH.—Annual Report of the Secretary for the year ending June 30, 1890.—Principal Meteorological Conditions in Michigan, 1890.
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ODESSA, METEOROLOGISCHES OBSERVATORIUM DER NEURUSSISCHEN UNIVERSITÄT.—Meteorologische Beobachtungen, 1892.
PARIS, BUREAU CENTRAL MÉTÉOROLOGIQUE DE FRANCE.—Annales, 1890.—Bulletin International, 1893.
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PARIS, SOCIÉTÉ MÉTÉOROLOGIQUE DE FRANCE.—Annuaire, July 1892 to June 1893.
PHILADELPHIA, AMERICAN PHILOSOPHICAL SOCIETY.—Proceedings, Nos. 139 to 141.
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PUEBLA, OBSERVATORIO METEOROLOGICO DEL COLEGIO DEL ESTADO.—Resumen correspondiente a cada dia, July 1892 to March 1893.
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SAN SALVADOR, INSTITUTO NACIONAL.—Observaciones meteorológicas, March to Sept. 1892.

SAN SALVADOR, OBSERVATORIO ASTRONÓMICO Y METEOROLÓGICO.—Anuario, 1893.

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Spannkräften des Wasserdampfes unterhalb 100° und daraus entspringende Differenzen der Correctionen von Siedethermometern je nach ihrer Verificationsart.—Zusammenstellung der Beschlusse der internationalen Meteorologen-Conferenzen von der Conferenz in Leipzig, Aug. 1872 bis und mit der Conferenz in München, Aug. 1891.

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APPENDIX VII.

REPORTS OF OBSERVATORIES, &c.

THE METEOROLOGICAL OFFICE.—Lieut.-Gen. R. Strachey, R.E., C.S.I., F.R.S., Chairman of Council; Robert H. Scott, M.A., F.R.S., Secretary; Nav. Lieut. C. W. Baillie, F.R.A.S., Marine Superintendent.

MARINE METEOROLOGY.—*Current Charts for all Oceans.*—In the last Memorandum appearing in this Report for the year 1892, it was stated that a considerable amount of information, some 25,000 observations in all, had been obtained from foreign authorities, in order to supplement the records of currents derived from English sources of information.

During the year now under review a further instalment of some 2,000 observations for the Pacific Ocean has been obtained from Germany, exhausting their data, and the Council are of opinion that they have now procured nearly all the trustworthy current observations in existence, at least in the archives of the various meteorological bureaus in Europe. The very anxious task of generalising the contents for publication must now be undertaken.

The Red Sea.—These charts are passing through the press. The twelve Monthly Wind Charts have all been signed for press, and the twelve Current Charts are now in an advanced stage.

The Meteorology of the South Sea.—This investigation has made steady progress during the year, but none of the final charts have as yet been placed in the engraver's hands.

The South Atlantic.—The preparation of logs and extraction of data for this district is being actively prosecuted. It will be understood that, as in the South Sea, the southern limit of the area to be discussed is given by the northern limit of the South Polar Ice.

A new edition of the *Barometer Manual for Seamen* is in hand.

WEATHER TELEGRAPHY.—The only change in the operations of this branch has been the abandonment of Mullaghmore as a station, owing chiefly to the difficulty of replacing satisfactorily the observer who died in the spring of 1893. There is an idea of establishing a station on Barra, in the Hebrides, but apparently the island is so hilly that wind reports would not be quite satisfactory.

The Office has since Michaelmas been in receipt of daily reports from Punta Delgada, in the Azores, through the kindness of Admiral de Brito Capello, of Lisbon, and of the Eastern Telegraph Company.

The Rain Tables for the decade 1881-90 are now in hand, and it is hoped that these will furnish information more complete, as to uniform geographical distribution of the stations, than anything which has yet appeared.

LAND METEOROLOGY OF THE BRITISH ISLANDS.—The volume of *Hourly Mean Readings for five-day periods for the Four Observatories* has been published for the year 1890, and that for 1891 is well advanced. The volume of *Observations from Stations of the Second Order* for 1889 is out, and that for 1890 may be expected in the course of the summer.

Mr. Dines' pressure tube anemometer has now been in operation on the roof of the Office for a year. Very interesting records have been obtained from it, especially during the storm of November 18th.

The records of bright sunshine for the seven observatories in connection with the Office have been tabulated hourly for the twelve years 1881-1892, and the results will be published with the hourly means for 1891.

A new edition of the *Instructions in the use of Meteorological Instruments*, now 19 years old, is in preparation, to bring the book more up to the present state of Meteorology.—*February 15th*, 1894.

ROYAL OBSERVATORY, GREENWICH.—W. H. M. Christie, M.A., F.R.S., Astronomer Royal.

The usual routine meteorological work has been maintained with regularity during the year 1893. The only important instrumental change made in the year is the additional gearing which has been applied to the driving clock of Osler's Anemometer, by means of which the recording sheet can, when desired, be made to travel twelve times as fast. This arrangement has been brought into use on many occasions for the registration of high winds with the utmost benefit, the variation in pressure being much better seen than with the ordinary time scale. Portions of the working parts of Robinson's Anemometer which appeared to be much worn, have been recently renewed. It is satisfactory, however, to note that an independent comparison made (shortly before the renewal of the worn parts) by Mr. C. Harding, of the Meteorological Office, of the results recorded by this instrument in the gales of November last with those recorded by the anemometer of the Kew Observatory, indicated that these instruments were then giving practically identical results.

The discussion of the observations of the temperature of the air throughout the 50 years 1841-1890 has been completed, and the abstracts are partly printed. Various interesting particulars, relating to extremes, &c., have been extracted from these voluminous tables, but have not yet been finally brought into shape for printing. The results of the magnetical reductions 1865-1882 mentioned in last year's report are not quite ready for press.

The close of the year was marked by the retirement of Mr. Ellis, after a long and honourable term of service in the Royal Observatory, extending through 50 years, 20 of which had been spent as Superintendent of the Magnetical and Meteorological Department. The loss of Mr. Ellis to the public service will be severely felt. Mr. W. C. Nash has been promoted to succeed him as Superintendent, and the vacancy thus caused has not yet been filled up.—*March 12th*, 1894.

ROYAL OBSERVATORY, EDINBURGH.—Ralph Copeland, Ph.D., F.R.A.S., Astronomer Royal for Scotland.

At the end of the first quarter of 1893 the preparation of the monthly and quarterly summaries of weather observations of 55 Scottish stations for the use of the Registrar-General for Scotland was transferred from the Edinburgh Royal Observatory to the Scottish Meteorological Society, by whose members the observations are made.

The daily meteorological readings at the Observatory have been continued, together with the observations of the rock thermometers. The old rain gauge on the roof, at a short distance to the south of the dome, caught some 30 per cent. less rain than a similar gauge on the grass 22 feet lower down; this is quite in accordance with previous experience.

The removal to Blackford Hill, which will probably be carried out about the close of the year, will afford an opportunity of commencing a fresh series of observations, in which self-recording instruments will be largely used. In particular it is expected that the records of wind at the new Observatory will be of special interest.—*February* 1894.

KEW OBSERVATORY OF THE ROYAL SOCIETY, RICHMOND, SURREY.—Charles Chree, M.A., Superintendent.

It is with deep regret that the Committee have to report the decease of the late Superintendent, Mr. G. M. Whipple, B.Sc., which occurred on February 8th, after a serious illness of more than seven months. He had been connected with the Observatory in various capacities for thirty-four years, and had filled the

office of Superintendent since 1876. Under his efficient management the work at the Observatory had been largely augmented in amount and variety, and the funds at its disposal for purchase of apparatus and extension of its premises had steadily increased.

During the earlier part of the year the work of the Observatory was carried out by Mr. Baker, the Chief Assistant, to the entire satisfaction of the Committee. They desire that his services should be specially recorded, and they are glad to state that the routine work of the Observatory has in no way suffered owing to the enforced absence of the Superintendent for the early months of the past year.

The Committee, having invited applications for the vacant post of Superintendent, selected from amongst the candidates Mr. Charles Chree, M.A., Fellow of King's College, Cambridge, Sixth Wrangler 1883, First Division Part III. of the Mathematical Tripos, and First Class in Part II. of the Natural Sciences Tripos, 1884. Mr. Chree entered on his duties on May 15th.

The self-recording instruments for the continuous registration of atmospheric pressure, temperature of air and wet-bulb, wind (direction and velocity), bright sunshine, and rain, have been maintained in regular operation throughout the year, and the standard eye observations for the control of the automatic records duly registered.

The "Willesden" prepared papers have been in daily use on the self-recording Beckley gauge, and although the curves obtained are clear and distinct, yet the defect of the lengthening of the sheets in wet weather has not been entirely overcome. Circular letters were sent to several prominent paper makers asking for samples of material, specially prepared, to be used in a very damp atmosphere; but of those obtained, only one sample (supplied by Messrs. Waterlow and Sons) showed no appreciable lengthening in the dampest atmosphere producible artificially. It has, however, some counterbalancing defects, which render its superiority to the Willesden paper for the purpose in view somewhat doubtful.

At the request of the Meteorological Office an investigation has been carried out as to the causes of fluctuations that present themselves in the value of the residual correction to barograph readings, which is deduced by comparison of simultaneous readings of the barograph and a standard barometer. An analysis was made of the value of the residual correction between May 1892 and October 1893, while numerous measurements were taken of the width of the temperature compensation to the barogram at different temperatures. The data obtained accounted for a very considerable part, at least, of the irregularities observed in the residual correction. A report embodying an analysis of the results has been sent to the Meteorological Office.

The electrograph has been in regular action during the year, but its performance on the whole has been rather unsatisfactory. Early in the year the needle-suspension being accidentally broken, another was fitted without delay, and a new determination made of the scale value. Subsequent re-determinations were carried out in May, July, and November. It is intended to take advantage of the first spell of frosty weather to dismount and thoroughly overhaul the instrument, and to open out the scale, which has for some time past been too contracted.

Operations connected with cloud photography have been suspended during the year.

The observation of a series of distant objects referred to in the last report has been continued. A note is taken of the most distant of the selected objects, which is visible at each observation hour. An analysis of the results for the period May 1892 to December 1893 is at present being carried out. During the thickest fog experienced in the past year, at one of the hours of observation the most distant object visible was only 12 feet off.

The mean temperature of the air for the year was 50°·9, and the extreme range 75°·5, from 18°·1 on January 5th to 88°·6 on August 17th. In the sun's rays the maximum, 139°, occurred on June 19th, and the lowest reading of a thermometer freely exposed on the grass was 7° on January 5th.

The year was remarkable for the drought during the spring, and for the very large amount of bright sunshine recorded, no less than 1,681½ hours being registered, giving a mean percentage of 35, the highest yearly value yet obtained. With the exception of January, July, and November, each month was well above the average, the maximum record of 59 per cent. in April being 27 per cent.

above the April mean for the past 16 years. The total rainfall was 19·50 ins.—*May* 1894.

RADCLIFFE OBSERVATORY, OXFORD.—E. J. Stone, F.R.S., Radcliffe Observer.

No change in the routine or staff has been made during the year. The Robinson Anemograph, having become much worn during the 18 years it had been mounted on the Observatory Tower, was replaced in July 1893 by a new one, which includes all the latest improvements, and is working well.

The other self-recording instruments have been working satisfactorily during the year. The gelatino-bromide paper is used for the photographic registers, and gives excellent results.

Eye readings have been taken as usual; and reports sent daily by telegram to the Meteorological Office, monthly to the Registrar-General and local press.

The following are the chief characteristics of the weather noted at Oxford during the year 1893:—

There was a remarkable absence of rain during the spring months; from March 4th to May 15th only 0·016 in. was registered at this Observatory. In June only one-third of the average amount fell, whilst August and September were much below the average: July, however, was 1·3 in. in excess of the average.

The total rainfall for the year was 18·596 ins., or 8 inches below the average for the preceding 78 years.

As regards temperature, the early part of January was marked by continued frost, with a minimum in the air on the 5th of 12°·9, and on the grass 7°·1; the average for the month being 2°·5 below the mean for the preceding 38 years. During the remaining months of the year, with the exception of November, the mean monthly temperatures were all high; those of March, April, May and August being respectively 4°·8, 5°·3, 4°·5, and 4°·1 above the average for the preceding 38 years. The maxima were 84°·3, 85°·7, 85°·6, 88°·1, and 88°·3 on the five consecutive days of August 14th, 15th, 16th, 17th and 18th.

Coincident with the defect of rainfall and excess of temperature, the excess of recorded bright sunshine was a marked feature of 1893, there being 365 hours recorded above the average for the last 13 years.—*January 22nd*, 1894.

REPORT ON THE

PHENOLOGICAL OBSERVATIONS FOR 1893.

BY EDWARD MAWLEY, F.R.Met.Soc., F.R.H.S.

(Plate II.)

[Read February 21st, 1894.]

THE number of observers sending in returns during 1893 was 117, showing a slight increase on the two previous years. The changes in the observing stations have been as follows:—No returns were received from Whitchurch Canonicorum, Tunbridge Wells, Canterbury, Beckenham, and Henley-on-Thames in District C.; Burton-on-Trent and Huddersfield in District D.; Chester, Settle, and Douglas (Isle of Man) in District F.; and Collon in District G. On the other hand, observations were sent in from the following new stations:—Mawnan Smith, West Bagborough, and Long Ash-

ton in District A.; Bembridge, (Isle of Wight), Bidborough, Swanley, Chislehurst, Bickley, Cranleigh, Ashtead, Croydon, Farley, and Whatley in District C.; Watford and Broxbourne in District D.; Ashwell in District E.; Penmaenmawr, and Cronkbourne and Sulby (Isle of Man) in District F.; and Cambois in District I.

All the eleven Districts are represented, but there are still only two observers in Ireland South (District B.), and but one observer in either Scotland East (District J.) or Scotland North (District K.). More observers in these three Districts are much needed, in order that they may be placed on something like an equal footing with the others. Returns from one or two stations only, which may chance to be either very exposed or sheltered, as the case may be, must necessarily represent but indifferently the climate of any considerable portion of our Islands.

The observations regarded as a whole are the best I have yet had the pleasure of tabulating, and the thanks of the Society are due to the Phenological Observers generally for sending in so many valuable and interesting returns. Not only have the observations been as a rule more carefully made than in the two previous years, but they are also more numerous. For instance, where the returns from the different stations contained on an average the dates of flowering of 8 of the 13 plants in 1892, there were to be found 9 entered in 1893.

The Winter of 1892-93.

December, taken as a whole, was a cold winter month, except in the south of Ireland, where the mean temperature comes out as slightly above the average. January also proved unseasonably cold, especially in the southern, eastern, and south-western districts of England, where the departures from the mean amounted to $-5°{\cdot}0$, $-4°{\cdot}5$, and $-3°{\cdot}8$ respectively. February, on the other hand, was mild in all the divisions—and very wet.

Until the middle of the fourth week in December the weather remained for the most part mild and dry throughout the greater part of the British Isles. In the warmer districts garden flowers were here and there to be seen in blossom until within a few days of Christmas, and at Scilly the first small gathering of daffodils was made shortly after the middle of the month. Then came four weeks of continued frost, which brought everything suddenly to a standstill, and penetrated the soil to an unusual depth, owing to the absence in most places of any covering of snow worth mentioning. The soil and atmosphere remaining unusually dry for the season, less injury was done to half-hardy vegetation generally than in previous winters when the cold was less intense and prolonged. In gardens vegetables appear to have suffered the most, particularly the more tender kinds, such as broccoli, celery, cauliflowers, &c. This proved a trying period for birds, and many perished from cold, and through their natural supply of food being cut off for weeks together, owing to the frozen state of the ground. Scarcely had the long frost broken up than winter aconites and other early flowers began to make their appearance in the south of England, showing how comple

the change in temperature must then have been. From this time until the end of the season mild and wet weather prevailed.

This winter quarter was by no means a favourable one to the farmer. The long continued frost not only kept the plough idle for weeks together, but also committed sad havoc among the turnips. Then again, the soil was so saturated by rain during February that any but light lands were rendered as unworkable as before.

The hazel came into flower later than its adopted average in all districts—the departures from the mean being smallest in the southern, midland, and eastern counties of England, and greatest in Ireland North, Scotland, and the north of England. The dates of flowering of the coltsfoot were as usual very irregular, but in most districts also rather later than the average. No doubt the great depth to which the long frost penetrated the ground in January helped to retard the blossoming of these two plants.

The song of the thrush was first heard a few days earlier than in either 1891 or 1892. The honey-bee first visited flowers about the same dates as in 1891, but a little earlier than in 1892.

The Spring.

This proved by far the most remarkable season of this remarkable year. In each of the three months the mean temperature was in every district considerably above the average—the departures for the quarter ranging from $+2°{\cdot}6$ in England North-east and in Scotland North, to $+4°{\cdot}4$ in the south-west of England. The total rainfall was much in defect of the mean—ranging from $-2{\cdot}1$ ins. in the north of Scotland to $-5{\cdot}3$ ins. in England South-west. The record of sunshine, too, if we omit Scotland and the north of Ireland, proved equally exceptional. In fact, in the south-western, southern, and midland counties of England the aggregate duration exceeded the mean by more than 200 hours.

Taking the British Isles as a whole, the most noteworthy feature of this season was its very exceptional earliness. Stimulated by the continued heat, vegetation of all kinds was everywhere forced on rapidly, and without any check worth mentioning, into leaf and flower, and in some cases into fruit, long in advance of its usual time. Even in parts of Scotland strawberries were gathered in May and new potatoes and peas ready for use.

Throughout nearly the whole of England, however, a persistent drought reigned supreme, and was there perhaps even more exceptional in its effects than the unseasonable warmth of the ground and atmosphere. In fact, until after the middle of May there did not occur a single week in which the fall of rain was not much below the average. Owing no doubt to the abundant rainfall in February, and the genial weather which followed, the trees in no way suffered. On the contrary, the general remark at the time seems to have been that their foliage appeared singularly abundant and well developed. Rarely have flowering trees and shrubs been seen to bloom so freely. Fruit trees especially were densely covered, but were soon out of blossom. The injurious influence of the drought upon the less deeply rooted plants was,

however, very marked. The fields and hedge-rows became unusually gay with spring and summer flowers, following each other in rapid succession after the middle of the season, but the dry and forcing weather soon told upon the plants themselves, stunting their growth, and causing their blossoms to fade before they were at their best.

After the middle of March the land was in splendid condition for getting in the spring corn, which has seldom had so favourable a seed bed. But in many instances the ground had become so dry that the grain failed to germinate at all, or came up very irregularly, and not until weeks, and sometimes months, after it had been sown. Garden seeds also germinated very slowly. The pastures were remarkably bare, and the farmers often at their wit's ends to provide sufficient fodder for their cattle and sheep.

But, after all, it should be borne in mind that many of the foregoing remarks only apply to about one half the area of the United Kingdom. For in some of the northern counties of England, as well as throughout Scotland and a great part of Ireland, there has scarcely ever been known a more favourable spring for crops of all kinds. For although the weather continued also unseasonably dry in these favoured districts, it was never injuriously so. For one thing, what is called a drought in the wetter parts of our islands is by no means so serious a matter as where the average rainfall is lighter, but last year these parts also appear to have been visited by heavy showers just at the times when they were becoming most needed by the growing crops.

I am unable to account satisfactorily for the wood anemone flowering so late as it did in many districts in such a warm March, unless it be that growing under the shelter of trees in shady spots the brilliant sunshine had not the same power in raising the temperature of the soil as where the ground had been fully exposed to its influence. In the south-west of England, as well as in some of the northern counties, it was three weeks behind the adopted mean. The blackthorn, on the other hand, bloomed from about a week to ten days in advance of the average dates, while garlic hedge mustard was in most districts about a fortnight earlier than usual. The horse chestnut was as a rule about three weeks in advance of the mean. The hawthorn was also about three weeks early, the white ox-eye about a fortnight early, while the dog rose flowered fully three weeks in advance of the average in several districts. At Marlborough the first flower of the hawthorn was noted on April 15th, which is not only 29 days earlier than its average for that station in the preceding 28 years, but 15 days earlier than in any of them. The white ox-eye also blossomed 6 days earlier than the earliest, and the dog rose 11 days in advance of the previous earliest record.

Three of the spring migrants on the list, the swallow, the cuckoo, and the nightingale, according to the returns, made their appearance in this country about a week earlier than in either of the two previous years. The flycatcher also arrived a trifle earlier than in 1892.

The wasp, the small white butterfly and orange tip butterfly were first seen from a fortnight to three weeks in advance of their average records for the two previous springs.

The Summer.

This was not nearly so abnormal a season as the one preceding it. Throughout June and the greater part of August the weather remained extremely warm, dry, and sunny, but in July, after the first week, the temperature was somewhat below the mean for the month, while the rainfall was for a time moderately heavy.

In England the memorable drought of 1893 may be said to have lasted 18 weeks—*i.e.* from the beginning of March until the end of the first week in July. During this period there occurred but one week, the third in May, when the rainfall was not below, being generally much below, the average.

On dry soils the lime trees began shedding their leaves before the end of June, and by August their foliage had become quite yellow. The hay crop, where gathered, proved one of the lightest on record, but was harvested in capital condition. The pastures also were so burnt up by the heat that the cattle and sheep suffered greatly, and in many parts of the country had to be turned into the growing corn. In the gardens vegetables made but poor growth, peas especially being in most places the worst failure. On the other hand, in some of the northern counties of England, as well as throughout Scotland and a great part of Ireland, both farm and garden crops appeared to appreciate the unusual warmth and were singularly luxuriant, owing to the timely arrival of copious rains whenever the ground was beginning to get, in any way, injuriously dry. In all parts of the British Isles trees, shrubs, and plants of all kinds came into bloom and fruit remarkably early. Indeed, many autumn flowers were out of blossom before the autumn began. The harvest, too, was remarkably early, being practically over by the end of the third week in August throughout the southern and midland counties of England.

The crop of strawberries, in all but the south-western and north-western divisions of England, and in Scotland, where it was about average, was a very poor one. Bush fruits, on the contrary, were everywhere unusually abundant.

The welcome and refreshing rains of July soon made themselves felt, and particularly in the improved appearance of the pastures, but the beneficial effect gradually passed away when they were over, so that by the end of the summer the grass fields in most parts of England had become as bare and brown as before.

The continued heat and sunshine proved favourable to insect life. For instance, as the observers' returns show, wasps were so numerous in many counties in England as to amount to a plague. Butterflies too are reported to have been singularly abundant, and the comparatively rare clouded-yellow butterfly again appeared rather frequently in many localities, but not, however, in such numbers as in 1892. The humming-bird-hawk moth was also noted as unusually abundant in the south and south-west of England, as well as in some of the midland counties.

The black knapweed flowered more than three weeks earlier than its average

TABLE I.—LIST OF OBSERVERS.

	Station.	County.	Height above sea-level.	Observer.
	A.		Ft.	
1	Marazion	Cornwall	40	F. W. Millett
2	Mawnan Smith	Cornwall	200	Miss R. Barclay
3	Falmouth	Cornwall	190	Miss Willmore
4	Liskeard	Cornwall	400	S. W. Jenkin, C.E.
5	Tiverton	Devon	270	Miss M. E. Gill
6	Westward Ho	Devon	100	H. A. Evans
7	Instow	Devon	250	H. M. W. Hinchliff
8	West Bagborough	Somerset	350	E. G. Aldridge, F.R.Met.Soc.
9	Sidcot	Somerset	200	W. F. Miller C. B. Rowntree
10	Long Ashton	Gloucester	280	Miss T. L. Dyke Miss H. Dawe
11	Clifton	Gloucester	300	G. C. Griffiths, F.E.S.
12	Penarth	Glamorgan	120	G. A. Birkenhead
13	Cardiff	Glamorgan	40	A. Pettigrew
14	Castleton	Glamorgan	80	F. G. Evans, F.R.Met.Soc.
15	Bassaleg	Monmouth	25	W. J. Grant
16	St. Arvan's	Monmouth	360	Miss Mabel Peake
17	St. David's	Pembroke	220	W. P. Propert, LL.D., F.R.Met.Soc.
18	Aberystwith	Cardigan	30	J. H. Salter, B.Sc.
	B.			
19	Killarney	Kerry	100	Ven. Archdeacon Wynne, F.R.Met.Soc.
20	Wicklow	Wicklow	10	Mrs. Wyndham Wynne
	C.			
21	Bembridge	Isle of Wight	80	C. Orchard
22	Blandford	Dorset	270	J. C. Mansell-Pleydell, F.G.S., F.L.S.
23	Buckhorn Weston	Dorset	290	Miss H. K. H. D'Aeth
24	Pennington	Hants	100	Miss E. S. Lomer
25	Strathfield Turgiss	Hants	200	Rev. C. H. Griffith
26	Bexhill-on-Sea	Sussex	10	H. Le Mesurier Dunn
27	Muntham	Sussex	250	Percy S. Godman, F.Z.S.
28	Dover	Kent	150	F. D. Campbell
29	Bidborough	Kent	420	Miss Mawley
30	Lynsted	Kent	140	R. M. Mercer, F.R.Met.Soc.
31	Farnborough	Kent	350	F. G. Minchin Kelly
32	Swanley	Kent	220	C. H. Hooper
33	Chislehurst	Kent	360	Miss F. Duncan
34	Bickley	Kent	300	Miss E. Scott
35	Coneyhurst	Surrey	600	J. Russell
36	Churt Vicarage	Surrey	350	Rev. A. W. Watson
36	Churt	Surrey	300	C. Criddle
37	Cranleigh	Surrey	180	Admiral J. P. Maclear, F.R.Met.Soc.
38	Winterfold	Surrey	580	R. Turvey
39	Willinghurst	Surrey	400	A. Nash
40	Oxshott	Surrey	210	W. H. Dines, B.A., F.R.Met.Soc.
41	Ashtead	Surrey	..	R. M. Prideaux
42	Addlestone	Surrey	100	C. U. Tripp, M.A., F.R.Met.Soc.
43	Croydon	Surrey	200	Miss Grahame
44	East Molesey	Surrey	40	Lady Jenkyns
45	Farley	Wilts	..	Miss F. C. Henderson
49	Salisbury	Wilts	150	W. Hussey
47	Marlborough	Wilts	480	E. Meyrick, B.A., F.Z.S.
48	Whatley	Somerset	450	C. G. Whittaker
49	Whitchurch	Oxford	150	Rev. J. Slatter, M.A., F.R.Met.Soc.
50	Reading	Berks	..	H. Goadby
	D.			
51	Oxford	Oxford	200	F. A. Bellamy, F.R.Met.Soc.
52	Cheltenham	Gloucester	250	M. L. Evans
53	Beckford	Gloucester	120	F. Slade, F.R.Met.Soc.

TABLE I.—LIST OF OBSERVERS—*Continued.*

Station.	County.	Height above sea-level.	Observer.
		Ft.	
D.			
54 Watford	Herts	250	Mrs. G. Bishop
55 Broxbourne	Herts	150	Lady Frances Bushby
56 St. Albans (The Grange)	Herts	380	Mrs. Hopkinson
56 St. Albans (Addiscombe Ldg.)	Herts	400	Miss E. F. Smith
56 St. Albans (St. Peter's Street)	Herts	380	H. Lewis
56 St. Albans (Newberries)	Herts	320	H. Lubbock
57 Berkhamsted	Herts	400	Mrs. E. Mawley
58 Harpenden	Herts	370	J. J. Willis
59 Ross	Hereford	210	H. Southall, F.R.Met.Soc.
60 Breinton	Hereford	230	H. A. Wadworth, F.R.G.S.
61 Evesham	Worcester	120	Rev. D. Davis, B.A.
62 Henley-in-Arden	Warwick	320	T. H. G. Newton, F.R.Met.Soc.
63 Northampton	Northampton	320	H. N. Dixon, M.A., F.L.S.
64 Churchstoke	Montgomery	550	P. Wright, F.R.Met.Soc.
65 Burbage	Leicester	430	C. C. Hurst, F.R.H.S.
66 Thurcaston	Leicester	250	Rev. T. A. Preston, F.R.Met.Soc.
67 Uppingham	Rutland	300	G. W. S. Howson, M.A.
68 Walsall	Stafford	450	W. F. Blay, F.R.Met.Soc.
69 Tean	Stafford	470	Rev. G. T. Ryves, F.R.Met.Soc. Miss G. M. B. Ryves
70 Beeston	Notts	210	G. Fellows, F.R.Met.Soc.
71 Hodsock	Notts	60	Miss Mellish, F.R.H.S.
72 Eaton	Notts	..	J. Cordeaux
73 Bakewell	Derby	400	Miss E. Taylor
74 Macclesfield	Cheshire	500	J. Dale
75 Belton	Lincoln	200	Miss F. H. Woolward
76 Harrogate	Yorkshire	340	J. Farrah
E.			
77 Hertford	Herts	140	W. Graveson
78 Hitchin	Herts	230	J. E. Little, M.A.
79 Ashwell	Cambridge	260	H. G. Fordham
80 Booking	Essex	240	H. S. Tabor, F.R.Met.Soc.
81 Lexden	Essex	90	Miss Carver
82 Sproughton	Suffolk	30	Rev. A. Foster-Melliar
83 Tacolneston	Norfolk	190	Miss E. J. Barrow
84 Wryde	Cambridge	10	S. M. Egar
F.			
85 Heswall	Cheshire	160	F. M. Sherwood
86 Penmaenmawr	Carnarvon	350	A. T. Johnson
87 Claughton	Lancashire	80	Mrs. Kent Green
88 Giggleswick	Yorkshire	500	E. Peake, M.A.
89 Ambleside	Westmoreland	320	S. A. Marshall
90 Egremont	Cumberland	160	J. Sherwen
91 Cronkbourne	Isle of Man	110	A. W. Moore J. Murphy
92 Orry's Dale	Isle of Man	70	Miss C. G. Crellin
93 Sulby	Isle of Man	80	H. S. Clarke, F.E.S.
G.			
94 Edgeworthstown	Longford	270	J. M. Wilson, B.A.
95 Loughbrickland	Down	350	Rev. H. W. Lett, M.A.
96 Saintfield	Down	310	Rev. C. H. Waddell, M.A.
97 Antrim	Antrim	70	Rev. W. S. Smith
98 Londonderry	Londonderry	450	T. Gibson
99 Ballynagard	Londonderry	30	Miss A. M. Campbell

TABLE I.—LIST OF OBSERVERS—*Continued.*

Station.	County.	Height above sea-level.	Authority.
		Ft.	
H.			
100 Dalshangan	Kirkcudbright	500	T. R. Bruce
101 Tynron	Dumfries	520	J. Shaw
102 Thornhill	Dumfries	300	J. Fingland
103 Jardington	Dumfries	100	J. Rutherford
104 Helensburgh	Dumbarton	100	Miss Muirhead
I.			
105 Doddington	Lincoln	90	Rev. R. E. Cole
106 Driffield	Yorks (E. R.)	80	The late J. Lovel, F.R.Met.Soc.
107 Thirsk	Yorks (N. R.)	120	A. B. Hall
108 East Layton	Yorks (N. R.)	570	Mrs. E. O. Maynard Proud
109 Durham	Durham	350	H. J. Carpenter
110 Low Fell	Durham	90	A. W. Price
111 Cambois	Northumberland	20	S. Dunnett
J.			
112 Aberdeen	Aberdeen	40	P. Harper
K.			
113 Inverbroom	Ross	50	J. A. Fowler

The numbers before the names of the Stations refer to their position on the map of the Stations, Plate II.

date in nearly all the English districts, but in England North-east, Scotland West, and Ireland North, the dates are about a week behind the adopted means. The harebell in most places blossomed from a week to three weeks earlier than usual. The greater bindweed, however, eclipsed all the other plants on the list as regards earliness, flowering as it did in nearly all parts of the country from a month to six weeks in advance of its usual time. At Marlborough, both the black knapweed and the harebell flowered in advance of the previous earliest record (1876-92).

The average date for the British Isles for the appearance of the meadow-brown butterfly was June 20th in 1891, and June 10th in 1892, whereas for 1893 it comes out as May 25th.

The Autumn.

Regarded as a whole, this was a cool, dry and sunny season. In September the temperature was about the average, in October somewhat above it, while November proved moderately cold throughout the month.

The second drought of the year began in England about the middle of August, and lasted in most districts seven weeks. This was again a most trying time for vegetation, indeed, more trying in many places than the previous drought owing to the greater dryness of the subsoil. Trees growing on porous lands consequently suffered much, and shed their leaves at an unusually early date. The pastures became as parched and brown as before, the growth of the root crops was checked, early apples and pears ripened prematurely, while comparatively few flowers were to be seen in the fields or gardens.

From the time that this second drought came to an end until the close of the season, vegetable growths of all kinds made as rapid and complete a recovery as was possible so late in the year. The rainfall being sufficiently abundant, and the ground having been warmed to a considerable depth, the green appearance of the grass was revived as if by magic, so that farmers no longer wanted for keep for their cattle, while the growing roots rapidly increased in size. The land was in a most favourable condition for working, and the autumn corn got in under the most advantageous circumstances.

One of the most noteworthy features of this autumn was the number of trees and shrubs which flowered a second time, to say nothing of numerous herbaceous plants. This does not appear to have been confined to any particular district, but was common throughout the country. The most frequent instances reported were those of the dog rose, bramble, dogwood, apple, pear and horse-chestnut. This second flowering was no doubt due to the shoots of these trees and shrubs having ripened and rested during the drought and then started afresh into active growth when the rains came. To similar causes must be attributed the second fruiting of strawberries and raspberries which was almost as frequently noted. In order to give some idea of how quickly growths were made and matured during the summer, two instances may be quoted from the observers' notes. In one case sweet peas are stated to have flowered last autumn from plants which had come up from the ripened peas shed from the pods of the summer crop. In another, small dahlia plants were sent to me which had grown in a similar way from self sown seed. Fields, too, were to be seen in October gay with a second crop of poppies in full flower. Wild fruits of all sorts were especially abundant, and more particularly acorns. But only in certain parts of the country were holly berries in any numbers to be met with. In most places the autumn tints were fine, owing to the gradual maturing of the foliage.

The ivy was first noted as in flower in all the warmer parts of our Islands from 10 days to a fortnight earlier than usual, but throughout the colder districts was in most places less than a week in advance of the mean. At Marlborough the ivy came into flower earlier than in any previous year (1876-92).

The swallow appears to have taken its departure a few days earlier than in the previous year.

As regards the autumn fruit crops, apples proved almost everywhere about an average crop, pears a poor crop, while plums yielded abundantly. In many places, notwithstanding the continued drought, the individual fruits of both apples and pears often attained an unusual size. Most of the early and mid-season kinds, however, kept badly after gathering.

The harvest in all parts of the Kingdom began at a singularly early date. The wheat crop was much under average in the Southern and Eastern districts of England and about average in the Midlands, but elsewhere the yield proved as a rule good, and the same remarks apply fairly well to barley and oats. Beans and peas were much below average in nearly all districts. Potatoes, on the contrary, were almost everywhere a good and sound crop. Turnips and mangolds yielded indifferently, except in England North-west

TABLE II.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1893.

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse Chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
A.													
Marazion	32	41	72	70	..	106	108	138	*117*	167	..	170	238
Mawnan Smith	..	..	..	..	..	96	113	131	129	164	..	184	244
Falmouth	36	41	88	67	..	104	110	130	133	148	..	155	..
Liskeard	35	53	89	75	107	104	111	..	130	..	..	..	..
Tiverton	34	56	79	81	95	105	107	..	..	..	..	..	268
Westward Ho	..	60	82	82	..	.	..	..	130	166	..	146	..
Instow	47	59	..	73	91	100	99	123	126	136	..	..	..
West Bagborough	..	..	..	..	94	95	110	117	128	134	..	..	..
Sidcot	..	50	71	87	94	99	111	119	130	..	..	..	
Clifton	..	..	84	87		99	110	130	128	..	..	..	..
Long Ashton	..	..	..	91	98	..	..	..	*145*	..	..	..	233
Cardiff	37	..	..	..	..	97	108	121	131	..	..	..	..
Castleton	33	46	67	74	91	91	110	124	129	146	184	141	231
Bassaleg	34	57	86	86	..	97	107	..	133	..	..	..	267
St. Arvans	30	64	68	88	98	108	112	130	134	..	..	164	233
St. David's	..	49	..	88	..	..	113	..	..	..	..	..	..
Aberystwith	27	56	80	77	88	111	105	109	131	146	168	160	242
B.													
Killarney	25	33	51	54	92	95	101	125	123	178	..	166	229
Wicklow	43	45	78	64	95	106	103	126	132	130	..	155	..
C.													
Bembridge	..	..	..	85	98	99	108	119	142	145	..	..	..
Blandford	27	63	71	83	100	110	111	116	136	145	192	*221*	*307*
Buckhorn Weston	36	48	77	84	92	110	108	119	129	135	..	136	249
Pennington	39	63	..	84	104	106	108	120	133	143	139	180	250
Strathfield Turgiss	38	65	67	89	98	109	114	123	134	140	135	143	263
Bexhill-on-Sea	45	..	71	88	109	102	109	133	144	..	..	..	290
Muntham	33	72	66	83	107	109	104	122	139	153	..	176	..
Dover	..	46	..	91	..	..	118	..	142	170	..	..	255
Bidborough	44	..	*104*	90	..	113	116	*146*	142	..	..	..	..
Farnborough	42	56	82	90	103	115	114	118	137	*191*	194	194	..
Swanley	33	59	86	..	111	..	117	..	..	..	185	..	..
Chislehurst	..	..	..	..	..	..	..	..	133	*198*	187	160	..
Bickley	..	..	81	90	109	111	113	138	142	..	..	..	..
Coneyhurst	39	67	73	87	120	125	116	128	121	..	170	196	*303*
Churt (Vicarage)	34	67	84	88	104	113	112	130	133	..	154	171	..
Churt	34	60	71	87	102	113	108	136	130	159	126	166	240
Winterfold	51	37	62	84	..	122	118	..	140	163	195	..	268
Willinghurst	33	..	79	..	..	109	106	..		..	..	..	259
Oxshott	43	..	76	85	..	..	..	127	137	162	..	175	..
Ashtead	39	63	75	89	103	114	121	131	..	..	..	..	..
Addlestone	48	61	85	88	105	112	112	130	138	150	193	157	..
Croydon	41	68	..	90	..	..	..	134	144	..	..	..	..
East Molesey	36	62	..	88	..	112	114	127	138	..	..	177	254
Farley	27	..	75	82	84	113	112	120	127	140	.	136	..
Salisbury	38	..	..	77	104	107	109	117	129	..	..	..	..
Marlborough	31	..	68	88	122	112	105	124	131	144	148	..	241
Whatley	39	..	..	..	99	104	116	127	..	160	*237*	*306*	..
Whitchurch	35	..	..	..	..	111	114	..	..	..	..	..	..
Reading	*62*	..	84	74	..	105	112	136	139	..	..	..	.
D.													
Oxford	..	..	..	..	95	102	110	..	135	142	..	..	253
Cheltenham	29	50	64	84	97	104	106	..	128	155	181	183	236
Beckford	35	64	70	83	100	108	108	117	125	143	161	154	236
Watford	37	*106*	*107*	86	103	114	112	*145*	144	..	..	..	..
Broxbourne	..	..	..	71	85	..	111	114	..	142	..	..	..	..

TABLE II.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1893—*Continued.*

District and Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse Chestnut.	Hawthorn.	White Ox Eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
D.													
St. Albans (The Grange)	36	..	72	87	100	105	113	130	133	..	..	..	242
St. Albans (Ad.Lge)	..	76	77	81	96	108	115	122	131	151	..	..	267
St. Albans (Newberries)	..	..	79	87	109	111	117	130	136	..	..	..	..
Berkhamsted	36	57	83	88	94	117	114	131	130	149	191	146	252
Harpenden	20	61	86	90	94	114	112	129	137	156	..	152	..
Ross	50	..	..	78	..	..	109	..	136	..	..	..	..
Breinton	33	65	67	84	91	113	109	129	130	146	196	166	247
Evesham	48	60	81	82	103	105	104	122	124	167	..	147	269
Henley-in-Arden	31	67	77	85	..	107	111	125	124	148	..	..	..
Northampton	42	72	..	91	105	113	113	125	133	166	..	170	249
Churchstoke	39	61	77	85	99	112	118	130	140	..	..	..	..
Burbage	..	..	92	94	..	109	114	..	150	..	..	..	..
Thurcaston	..	..	84	90	96	115	109	131	139	139	..	..	..
Uppingham	37	60	72	85	98	..	108	126	131	145	..	..	..
Walsall	35	50	81	94	106	120	116	140	151	182	183	200	273
Tean	67	..	79	96	..	..	117	..	140	..	..	..	..
Beeston	30	39	..	89	..	114	114	141	147	158	..	..	..
Hodsock	24	65	80	84	104	113	113	143	141	176	188	163	253
Eaton	..	..	..	91	..	..	117	..	141	..	..	..	..
Bakewell	68	70	82	99	116	129	123	146	153	179	186	..	..
Macclesfield	59	87	95	106	..	115	116	144	149	182	185	187	269
Belton	21	67	72	..	113	116	111	131	136	162	..	183	261
Harrogate	34	51	88	99	104	120	128	151	150	165	194	179	268
E.													
Hertford	36	50	71	68	90	113	106	131	139	151	187	148	253
Hitchin	35	48	69	83	96	115	106	129	133	138	..	169	247
Ashwell	..	..	..	87	..	..	110	..	133	..	..	..	..
Bocking	30	48	88	92	108	109	119	137	135	*188*	..	190	226
Lexden	46	..	..	87	..	99	113	..	..	..	..	..	..
Sproughton	29	..	73	93	110	112	118	124	135	..	..	..	260
Tacolneston	32	71	..	..	..	100	..	..	..	157	..	..	245
Wryde	60	61	79	84	..	114	113	..	..	..	..	..	..
F.													
Heswall	..	42	..	99	..	109	86	135	*128*	..	..	..	..
Penmaenmawr	..	..	77	79	103	105	110	*112*	140	..	185	158	242
Claughton	..	..	..	..	..	..	119	142	142	167	184	177	..
Giggleswick	37	67	91	96	112	120	127	141	145	156	160	166	245
Ambleside	30	81	..	97	..	..	122	..	..	..	..	..	296
Egremont	43	46	83	92	113	115	115	131	137	152	166	156	247
Cronkbourne	..	*121*	..	78	126	122	125	..	..	..	..	*224*	269
Orry's Dale	70	92	96	98	..	110	113	132	135	..	163	153	242
G.													
Edgeworthstown	58	..	79	87	..	116	122	..	140	..	..	..	..
Loughbrickland	66	69	89	91	..	111	121	139	140	..	..	..	264
Saintfield	..	..	78	90	..	116	125	142	146	190	..	180	247
Antrim	46	68	..	89	..	116	..	136	137	181	..	194	255
Londonderry	54	75	84	103	..	118	123	141	149	200	..	206	..
Ballynagard	33	72	..	..	..	108	..	..	..	..	..	178	..
H.													
Dalshangan	49	82	..	101	..	..	..	..	..	..	..	..	..
Tynron	65	84	94	100	..	130	134	151	147	201	182	..	..
Thornhill	39	79	106	96	125	..	125	141	138	..	..	..	..
Jardington	38	69	86	103	..	..	125	138	..	183	176	..	..
Helensburgh	41	74	98	97	113	117	126	144	146	198	..	162	231

TABLE II.—DATE (DAY OF YEAR) OF FIRST FLOWERING OF PLANTS, 1893—*Continued*.

Station.	Hazel.	Coltsfoot.	Wood Anemone.	Blackthorn.	Garlic Hedge Mustard.	Horse Chestnut.	Hawthorn.	White Ox-eye.	Dog Rose.	Black Knapweed.	Harebell.	Greater Bindweed.	Ivy.
I.													
Doddington	63	64	79	91	109	114	116	138	145	..	..	..	..
Driffield	39	46	..	96	..	133	132	..	155	184	..	187	262
Thirsk	38	47	67	85	108	114	110	140	142	173	184	180	268
East Layton	67	66	97	100	120	124	132	148	159	199	193	..	261
Durham	48	61	83	100	..	131	129	146	147	..	165	..	*314*
Low Fell	71	84	90	..	..	142	130	..	159	196	197	205	268
Cambois	..	52	84	93	*147*	..	132	153	160	..	182	191	..
J.													
Aberdeen	..	74	114	..	..	135	132	160	161	..	196	..	..
K.													
Inverbroom	51	58	102	103	..	114	110	..	141	..	..	..	..

The dates in italics have not been taken into consideration when calculating the means given in Table III. (pp. 138-9).

Explanation of the dates in the Tables.

1– 31	are in January.	182–212	are in July.
32– 59	„ February.	213–243	„ August.
60– 90	„ March.	244–273	„ September.
91–120	„ April.	274–304	„ October.
121–151	„ May.	305–334	„ November.
152–181	„ June.	335–365	„ December.

and North-east, and also throughout Scotland and Ireland. The crop of hay was however the worst of the year. (See Table IV.). Sir John Lawes directed attention at the time to three noteworthy features in the English corn-crops, viz. 1. The poor yield; 2. The good quality of the grain; and 3. The shortness of the straw.

The Year 1893.

In complete contrast to the phenological year of 1892, this proved singularly forward one throughout the Kingdom. The February and March plants were certainly as a rule later than usual in coming into blossom, and more especially was this the case in all the colder parts of our Islands, but after this the dates were everywhere more or less in advance of the average, and during the height of the flowering season the departures from the mean were often considerable.

The year 1893 was one of the worst agricultural years ever known throughout fully two-thirds of England, whereas in Scotland the crops all round, with the exception of hay, have seldom been more abundant. The only redeeming feature of this generally disastrous year was the autumn, which proved everywhere exceptionally favourable to the farmer. Moreover, it would be difficult to estimate at its true value the benefits the land must have received through the disintegrating effect of the frost of last winter, followed as it was by the fertilising influence of nine months of almost uninterrupted sunshine.

Observers' Notes.

DECEMBER, 1892.—*Tiverton* (A.). We have roses and Christmas roses open at the same time. *Wicklow* (B.). 26th. All tropæolums killed by frost. *Pennington* (C.). Redwings, fieldfares, green and golden plover numerous by the end of the month. 23rd. Picked a bunch of primroses in a copse. *Burbage* (D.). 25th. Wallflowers in bloom until cut by last night's frost. *Inverbroom* (K.). 1st. Noticed a very large flock of snow bunting at sea-level, a very rare occurrence on the west coast. 5th. Shot three grouse in the valley not 100 ft. above sea-level, where grouse had never been seen before.

JANUARY, 1893. *Aberystwith.* (A.). 6th and 7th. Great rush of migrants down the coast, caused by the first decided snowfall of the winter. Many thousands of starlings and skylarks passed. 8th. Picked up several starved and crippled larks. *Pennington* (C.). 20th. Winter aconite in flower. *Strathfield Turgiss* (C.). 22nd. Winter aconite in flower. *Churt* (C.). 23rd. Winter aconite in flower. *Addlestone* (C.). 31st. Winter aconite in flower. *Whatley* (C.). 23rd. Winter aconite in flower. *Cheltenham* (D.). The severe frost tried vegetation very much, and all the cabbage tribe suffered severely. *Beckford* (D.). There being no snow on the ground, vegetation suffered much during the long frost—all the celery frosted, and spring cabbage killed. *Berkhamsted* (D.). Owing to the great depth to which the frost penetrated the ground, all my montbretias and globe artichokes were killed. The latter had passed through the previous eight winters without serious injury. 24th. Winter aconite in flower. *Ross* (D.). Frost destructive to many half hardy plants owing to the suddenness with which it set in. *Churchstoke* (D.). Swedes have stood the frost, but it destroyed the turnips. *Lexden* (E.). 25th. Winter aconite in flower. *Penmaenmawr* (F.). Fieldfares, redwings, and song thrushes suffering very much from severe frost and snow. *Edgworthstown* (G.). 22nd. Snowdrop in flower. *Tynron* (H.). Half the shoots on a Gloire de Dijon trained up the house wall were killed by frost. *Driffield* (I.). Turnips much damaged by frost. *Durham* (I.). Wild ducks have been very scarce. Lapwings left during the frost, but returned on 23rd. *Cambois* (I.). Turnip crop much injured by frost.

FEBRUARY.—*Aberystwith* (A.). 4th. Frog spawn seen. *Blandford* (C.). 10th. The first adder seen here. They are very common this year. My keeper, without moving, shot seven basking in some underwood, besides several curled up together. Frog spawn seen. *Pennington* (C.). No spring corn put in, owing to constant wet weather. 11th. Frog spawn seen. *Croydon* (C.). 10th. Winter aconite in flower. *Whatley* (C.). 2nd. Primroses in flower. *Harrogate* (D.). 19th. First frog spawn. *Dalshangan* (H.). 4th. Winter aconite in flower.

MARCH.—*Marazion* (A.). 23rd. Sand martins and wheatears first seen. *Mawnan Smith* (A.). 21st. Chiff-chaff seen. *Bassaleg* (A.). 26th. Sycamore in full leaf. *Wicklow* (B.). 16th. Foliage of trees, &c., extraordinarily heavy and good. Crops so far promise well. *Bembridge* (C.). 4th. Gathered mushrooms in two different places. 5th. Elms in bloom. 30th. Humming bird-moth seen. *Pennington* (C.). A splendid March for working the land. 17th. First blackbird's egg. *Swanley* (C.). 31st. Cherry in flower. *Bickley* (C.). 12th. Painted-lady butterfly seen. *Churt* (C.). Damage done by frost to my tea roses exceptionally great. 19th. Gloire de Dijon rose in flower on a south-east wall. *Addlestone* (C.). 15th. Almond in flower. *Whatley* (C.). 25th. Insects abundant, especially butterflies and beetles. *Cheltenham* (D.). 12th. Almond in blossom. *Watford* (D.). Cherry trees in full blossom. *St. Albans* (*Newberries*) (D.). 20th. Frog spawn seen. *Churchstoke* (D.). 18th. Frog spawn seen. *Thurcaston* (D.). The severe frosts of this month did much damage to blossoms. Laburnums in some places had but one flower on a raceme, and the horse-chestnuts lost large quantities of flowering shoots. *Belton* (D.). 12th. Wryneck heard and seen. *Helensburgh* (H.). 21st. Hedges quite green. *Thirsk* (I.). 29th. Butterflies unusually abundant for the time of year.

APRIL.—*Marazion* (A.). 11th. Clouded-yellow and brimstone butterflies seen. *Mawnan Smith* (A.). 24th. Gooseberries ¼ to ¾ in. long. *Clifton* (A.). 19th. Swarm of bees taken. *St. Arvan's* (A.). 10th. White butterflies numerous. *Aberystwith* (A.). Lilacs and all fruit trees in full bloom by end of

TABLE III.—MEAN DATES (DAY OF YEAR) FOR THE FIRST FLOWERING OF PLANTS IN 1893, AND THEIR VARIATIONS FROM THE AVERAGE.

Plants.	A. Eng. S.W.			B. Ireland, S.			C. Eng. S.			D. Eng. Mid.		
	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.
Hazel	33	23	+10	34	21	+13	38	31	+ 7	39	35	+ 4
Coltsfoot	53	44	+ 9	39	42	— 3	60	52	+ 8	62	56	+ 6
Wood Anemone	79	58	+21	65	56	+ 9	75	66	+ 9	79	70	+ 9
Blackthorn	80	91	—11	59	91	—32	86	91	— 5	89	93	— 4
Garlic Hedge Mustard	95	111	—16	94	111	—17	104	111	— 7	101	113	—12
Horse Chestnut	101	126	—25	101	126	—25	111	126	—15	112	128	—16
Hawthorn	109	131	—22	102	131	—29	112	131	—19	113	133	—20
White Ox Eye	125	139	—14	126	139	—13	126	139	—13	132	141	— 9
Dog Rose	130	156	—26	128	160	—32	136	155	—19	138	158	—20
Black Knapweed	151	175	—24	130	179	—49	151	174	—23	158	177	—19
Harebell	176	189	—13	..	*193*	..	168	188	—20	184	191	— 7
Greater Bindweed	160	195	—35	161	199	—38	167	194	—27	169	197	—28
Ivy	245	263	—18	229	266	—37	257	270	—13	255	274	—19
Mean for the 13 Plants	118	131	—13	106	127	—21	122	133	—11	125	136	—11

Plants.	E. Eng. E.			F. Eng. N.W.			G. Ireland, N.			H. Scotland, W.		
	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.
Hazel	38	36	+ 2	45	32	+13	51	29	+22	46	33	+13
Coltsfoot	56	57	— 1	66	53	+13	71	50	+21	78	54	+24
Wood Anemone	76	71	+ 5	87	67	+20	83	64	+19	96	68	+28
Blackthorn	85	95	—10	91	97	— 6	92	97	— 5	99	99	Av.
Garlic Hedge Mustard	101	115	—14	114	117	— 3	..	*117*	..	119	119	Av.
Horse Chestnut	109	130	—21	114	132	—18	114	132	—18	124	134	—10
Hawthorn	112	135	—23	119	137	—18	123	137	—14	128	139	—11
White Ox Eye	130	143	—13	136	145	— 9	140	145	— 5	144	147	— 3
Dog Rose	135	157	—22	140	161	—21	142	164	—22	144	164	-20
Black Knapweed	149	176	—27	158	180	—22	190	183	+ 7	194	183	+11
Harebell	187	190	— 3	172	194	—22	..	*197*	..	179	197	-18
Greater Bindweed	169	196	—27	162	200	—38	190	203	—13	162	203	-41
Ivy	246	273	—27	257	271	—14	255	271	—16	231	273	-42
Mean for the 13 Plants	123	136	—13	128	137	— 9	132	134	— 2	134	139	— 5

\+ indicates the number of days later than the average date.
— „ „ „ earlier „ „
Av. „ average date.

N.B.—The dates in italics have not been taken into consideration when calculating the mean dates at the bottom of the Table, nor the means for the British Isles.

first week. *Bembridge* (C.). 9th. Cuckoos and swallows numerous. 20th. Clouded yellow butterfly seen. *Buckhorn Weston.* (C.). 26th. Horse-chestnuts and hawthorns in full flower. *Pennington* (C.). Vegetables getting very scarce. Plants coming quickly into bloom, but flowers soon over. Pasture grass burnt up and feed very scarce—mangolds having to be drawn to the cattle

TABLE III.—MEAN DATES (DAY OF YEAR) FOR THE FIRST FLOWERING OF PLANTS IN 1893, AND THEIR VARIATIONS FROM THE AVERAGE—*Continued.*

Plants.	I. Eng. N.E.			J. Scotland, E.			K. Scotland, N.			British Isles.		
	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.	1893.	Approximate Average.	Variation from Average.
Hazel	54	37	+17	..	*38*	..	51	37	+14	43	31	+12
Coltsfoot	60	58	+ 2	74	59	+15	58	58	Av.	62	53	+ 9
Wood Anemone	83	72	+11	114	73	+41	102	72	+30	85	67	+18
Blackthorn	94	102	— 8	..	*103*	..	103	110	— 7	88	97	— 9
Garlic Hedge Mustard	112	122	—10	..	*123*	..	..	*130*	..	105	115	—10
Horse Chestnut	126	137	—11	135	138	— 3	114	145	—31	115	132	—17
Hawthorn	126	142	—16	132	143	—11	110	150	—40	117	137	—20
White Ox Eye	145	150	— 5	160	151	+ 9	..	*158*	..	136	144	— 8
Dog Rose	152	163	—11	161	166	— 5	141	173	—32	141	162	—21
Black Knapweed	188	182	+ 6	..	*185*	..	..	*192*	..	163	179	—16
Harebell	184	196	—12	196	199	— 3	..	*206*	..	181	193	—12
Greater Bindweed	191	202	—11	..	*205*	..	..	*212*	..	170	199	—29
Ivy	265	274	— 9	..	*277*	..	..	*276*	..	249	271	— 22
Mean for the 13 Plants	137	141	— 4	139	133	+ 6	97	106	— 9	127	137	—10

\+ indicates the number of days later than the average date.
— „ „ „ earlier „ „
Av. „ average date.

N.B.—The dates in italics have not been taken into consideration when calculating the mean dates at the bottom of the Table, nor the means for the British Isles.

daily. The medlar flowered 35 days earlier than in 1892. *Strathfield Turgiss* (C.). The wet February and dry warm March have produced early movements on the part of the birds, but vegetation generally is backward. *Swanley* (C.). 29th. Commenced picking gooseberries for market. *Chislehurst* (C.). Poisonous adder killed over 2 ft. long, none of the sort seen for 20 years. *Bickley* (C.). 20th. White water-lily in flower. *Coneyhurst* (C.). 30th. An oak in leaf and quite green. *Churt* (C.). 2nd. Wryneck first heard—an unusually early date. *Addlestone* (C.). At the end of the month hedge sides and fields were covered with flowers, and the trees with leaves. *East Molesey* (C.). 30th. The horse-chestnut avenue in Bushey Park now in full bloom—a remarkably early date. *Salisbury* (C.). A garden crab watched for 17 consecutive years flowered on the 4th, or three days later than in 1882. In 1879 it did not open a flower till May 22nd. *Whitchurch* (C.). 21st. Elms so fully out as to make complete shade. *Reading* (C.). 23rd. The river (Thames) is gradually falling, and is now 2 ft. below the usual level at this time of year. *Oxford* (D.). Hawthorn in flower on 20th, 13 days earlier than the previous earliest date, 1882. *Beckford* (D.). 14th. The blossom on the cherries, plums, and pears, damaged by frost. *St. Albans* (*Addiscombe Lodge*) (D.). Seeds, in spite of being watered, refused to germinate till rain came. Sweet peas sown March 20th came up April 18th. *Watford* (D.). 8th. Wryneck first seen and heard. *Berkhamsted* (D.). 1st. A wild cherry in flower a month in advance of the previous 7 years' average. *Ross* (D.). 3rd. 41 different wild plants noted in one week. *Breinton* (D.). 14th. Oaks and elms came into leaf together. *Burbage* (D.). Cuckoos unusually numerous this year. *Walsall* (D.). 17th. Orchards in full blossom. Have never known such a display of bloom in this district. *Beeston* (D.). The swallow was first seen two days later, and the cuckoo heard five days earlier than their respective average dates for the previous 18 years. 14th. Apples, cherries, and damsons in full bloom. *Hodsock* (D.). 1st. Wild cherry in flower. 24th. Elms in leaf and some oaks, but no beeches. *Harrogate* (D.). Apples, pears, and cherries generally in bloom. *Hitchin* (E.). Swift first seen.

TABLE IV.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1893.

Station.	Song.	Migration.					Insects.				
	Song Thrush First heard.	Swallow First seen.	Cuckoo First heard.	Nightingale First heard.	Flycatcher First seen.	Swallow Last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
A.											
Marazion	33	103	107	..	..	279	79	82	85	123	154
Mawnan Smith	..	109	110	..	*81*	..	..	..	79	123	158
Falmouth	..	..	..	..	..	..	..	104	80	127	..
Liskeard	20	101	108	..	127	266	64	90	81	124	136
Tiverton	..	..	..	..	..	291	..	..	..	..	..
Westward Ho	24	87	103	..	..	..	..	..	71	99	152
Instow	..	107	113	..	..	..	59	85	86	97	146
West Bagborough	..	106	100	..	..	..	..	91	89	100	..
Sidcot	..	80	103	113	125	..	83	88	103	63	116
Clifton	..	..	93	113	..	..	..	81	88	93	142
Long Ashton	..	98	93	..	144	..	18	..	..	105	..
Penarth	..	..	..	..	..	..	72	78	80	106	146
Cardiff	35	96	109	..	141	283	50	88	..	..	..
Castleton	34	87	107	112	142	288	50	85	86	95	123
Bassaleg	31	106	107	112	..	291	38	60	..	..	..
St. Arvan's	28	105	107	110	134	282	22	45	81	100	160
St. David's	..	77	110	..	..	..	73	..	99	125	..
Aberystwith	25	94	109	..	129	271	..	..	87	109	154
B.											
Killarney	18	95	116	..	..	..	68	79	89	101	..
Wicklow	*107*	77	110	..	..	..	65	97	84	92	124
C.											
Bembridge	..	87	90	103	..	302	78	89	78	144	110
Blandford	..	99	103	100	130	277	61	84	91	92	145
Buckhorn Weston	13	99	101	..	..	..	25	99	..	91	128
Pennington	28	101	100	108	137	293	35	79	88	111	155
Strathfield Turgiss	49	93	100	103	115	275	79	93	92	108	135
Bexhill-on-Sea	28	101	103	101	122	*324*	88	94	88	123	144
Muntham	30	94	101	105	142	..	63	91	94	109	..
Dover	..	..	..	..	..	301	..	..	..	..	..
Bidborough	..	..	104	..	..	..	66	..	90	..	..
Lynsted	..	111	110	111	..	..	..	..	..	..	..
Swanley	..	..	108	..	..	..	..	..	88	141	..
Chislehurst	..	109	104	104	..	282	..	..	88	112	..
Bickley	..	106	108	106	130	..	50	81	83	115	..
Coneyhurst	36	102	99	104	130	278	50	81	93	..	..
Churt Vicarage	31	100	107	114	..	284	50	95	87	109	*170*
Churt	41	85	104	106	126	..	50	56	93	96	..
Cranleigh	..	..	100	94	..	288	..	..	..	..	..
Winterfold	49	96	100	102	118	285	50	55	..	..	..
Willinghurst	35	..	100	106	..	269	..	88	94	..	..
Oxshott	31	109	106	113		286	..	63	..	..	..
Ashtead	..	105	105	104	..	..	50	..	85	99	133
Addlestone	30	96	93	101	99	277	50	50	84	..	..
Croydon	37	.	..	..	..	..	50	102	92	..	..
East Molesey	24	103	110	108	..		51	84	104	125	..
Farley	..	..	102	106	..		..	..	..	..	..
Salisbury	..	110	..	..	..	291	..	..	80	..	..
Marlborough	35	98	109	109	128	..	..	..	82	113	..
Whatley	24	100	108	109	*154*	281	50	84	84	107	161
Whitchurch	23	..	111	110	..	..	84	..	..	..	..
Reading	91	..	91	*122*		..	..	73	..	121	..
D.											
Oxford	..	93	107	.	..	..	..	..	86	..	140
Cheltenham	29	105	105	114	128	283	50	80	83	99	135

ABLE IV.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1893—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song Thrush First heard.	Swallow First seen.	Cuckoo First heard.	Nightingale First heard.	Flycatcher First seen.	Swallow Last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
D.											
ord	22	102	105	104	136	275	22	94	98	108	129
rd	24	105	104	106	*160*	..	62	..	79	107	..
ourne	..	..	108	108	..	..	..	108	91	..	..
lbans (The Grange)	..	..	..	..	..	..	50	..	84	..	..
lbans (Add. Lodge)	..	122	113	111	..	..	..	96	84	106	..
bans (St. Peter's Street)	29	98	99	106	148	283	..	..	..	..	..
lbans (Newberries)	..	98	104	108	127	..	68	82	92	..	..
amsted	29	105	100	109	131	..	50	75	80	103	..
enden	..	108	97	108	..	..	..	119	89	112	128
	25	109	109	..	136	..	39	79	83	..	..
ton	40	104	109	..	145	280	51	59	50	94	*181*
am	50	90	107	103	..	282	61	64	82	118	161
y-in-Arden	..	106	92	109	124	..	63	67	..	109	..
ampton	..	99	92	107	134	..	50	..	87	..	..
bstoke	45	..	102	..	..	..	50	88	89	93	..
age	18	106	106	109	138	281	50	93	63	126	..
caston	..	102	..	..	..	..	..	111	97	108	..
gham	..	105	108	112	..	..	70	59	..	108	..
all	44	111	113	..	..	275	50	94	93	..	..
	25	108	106	..	..	281	50	..	95	112	..
on	22	109	113	..	..	..	50	68	78	123	..
ock	30	101	110	111	131	282	24	97	108	111	..
n	..	109	110	107	122	..	50	..	..	..	..
well	..	94	117	..	..	..	66	..	95	..	..
lesfield	45	113	115	..	..	273	..	80	96	144	..
n	20	105	108	106	131	285	46	94	81	112	159
ogate	29	104	95	..	120	294	67	88	..	..	..
E.											
ford	..	..	..	..	..	292	..	..	..	..	..
in	32	98	109	94	..	..	31	94	93	112	..
ell	..	100	107	106	136	285	50	..	..	..	..
ing	..	..	109	113	..	..	..	..	..	..	..
en	26	109	109	109	140	280	49	95	87	111	148
ghton	30	112	111	105	133	287	50	88	83	108	124
lneston	30	..	..	..	..	..	25	..	..	..	..
le	..	110	115	..	118	..	67	..	115	..	123
F.											
rall	28	97	103	..	125	..	58	61	..	121	..
naenmawr	..	106	107	..	114	..	79	81	85	96	163
ghton	..	112	115	..	..	..	..	..	..	..	..
leswick	27	105	115	..	138	279	50	..	105	..	..
leside	33	107	116	..	118	..	93	117	.	113	..
mont	27	101	109	..	127	277	41	85	92	117	169
kbourne	29	*135*	123	..	..	299	25	87	117	118	134
's Dale	25	*124*	112	..	..	..	34	95	..	..	..
y	*79*	110	121	..	..	253	58	89	125	..	140
G.											
worthstown	22	95	112	..	124	292	90	81	88	..	..
hbrickland	31	96	110	..	..	273	60	32	109	110	..
tfield	..	102	114	..	..	..	67	113	100	113	170
im	35	111	117	..	127	275	50	96	100	113	..
londerry	33	109	112	..	..	..	..	99	112	114	172
magard	22	95	112	..	..	280	..	83	..	112	168
H.											
hangan	31	110	114	..	..	259	51	97	112	..	..

TABLE V.—DATE (DAY OF YEAR) OF SONG AND MIGRATION OF BIRDS, AND FIRST APPEARANCE OF INSECTS, 1893—*Continued.*

Station.	Song.	Migration.					Insects.				
	Song Thrush First heard.	Swallow First seen.	Cuckoo First heard.	Nightingale First heard.	Flycatcher First seen.	Swallow Last seen.	Honey Bee.	Wasp.	Small White Butterfly.	Orange Tip Butterfly.	Meadow Brown Butterfly.
H.											
Tynron	49	100	112	..	..	..	79	93	112	..	..
Thornhill	..	113	113	..	..	..	67	80	..	..	..
Jardington	36	113	115	..	139	..	..	97	109	..	166
Helensburgh	23	105	114	..	..	..	82	96	97	..	..
I.											
Doddington	..	..	109	..	..	..	..	..	..	..	..
Driffield	46	109	114	..	..	297	..	64	94	..	..
Thirsk	29	102	115	..	..	293	29	64	76	115	..
East Layton	37	114	105	..	136	274	49	71	100	129	168
Durham	30	112	121	..	..	290	91	51	109	..	..
Low Fell	33	118	109	..	..	273	..	112	..	..	..
Cambois	47	112	115	..	..	263	..	..	112	..	..
J.											
Aberdeen	28	119	121	..	130	272	81	131	128	..	..
K.											
Inverbroom	..	111	122	..	..	..	60	65	102	110	..
Mean Dates for the British Isles in 1893	31 Jan. 31st	103 April 13th	107 April 17th	107 April 17th	130 May 10th	282 Oct. 9th	56 Feb. 25th	84 March 25th	91 April 1st	110 April 20th	145 May 25th
Mean Dates for 1891–2	Feb. 4th	April 19th	April 25th	April 25th	May 10th	Oct. 15th	Feb. 27th	April 12th	April 16th.	May 13th	June 15th

The dates in italics have not been taken into consideration when calculating the means for the British Isles.

Penmaenmawr (F.). 6th. Cuckoos very plentiful. *Gigglewick* (F.). I have never before seen such blossom on the sycamore and ash. *Saintfield* (G.). 8th. Never remember to have seen the hedges so green so early in the year. *Inverbroom* (K.). 29th. Lilac in flower.

MAY.—*Marazion* (A.). The drought has had a disastrous effect on the staple produce of this district, potatoes and broccoli. One grower planted one ton of potatoes in a meadow, and the produce weighed exactly one ton and nine pounds. *Marwan Smith* (A.). Fruit blossom abundant. 18th. Swift seen. 31st. Hay being cut, very poor crop. Cows turned into uncut hay. *Falmouth* (A.). 14th. Ripe wild strawberries gathered. *Liskeard* (A.). Trees and shrubs flowering very freely. Owing to drought and sunshine everything brought very rapidly to maturity. Scarcely any hay. *Sidcot* (A.). Many wild plants appear in a very stunted form, especially the orchis, many being in full flower and less than an inch high. *Clifton* (A.). Blackthorns, hawthorns, and chestnuts were thickly covered with blossom, but owing to the great heat the flowers quickly faded. The emergence of insects was remarkably early. *Long Ashton* (A.). The grass has been entirely burnt up, and for some few days smelt just like hay. *Penarth* (A.). The warm weather caused insects to appear in great numbers during the spring. The different species of lepidoptera were about a month earlier than usual. *Castleton* (A.). All grass lands suffered and remained bare for lack of moisture. The nightingale, which only visits these parts in exceptionally fine seasons, was in full song. *Bassaleg* (A.). 30th. Wheat in full ear. *St. Arvan's* (A.). Pasture lands very bare and brown. *St. David's* (A.).

TABLE V.—Estimated Yield of Farm Crops in 1893.

Description of Crop.	England. A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.	Scotland. H. W.	J. E.	K. N.	Ireland. B. and G. S and N.	British Isles.
Wheat	2% O. Av.	21% U. Av.	4% U. Av.	17% U. Av.	15% O. Av.	7% O. Av.	14% O. Av.	3% O. Av.	39% O. Av.	Av.	U. Av.
Barley	14% U. Av.	35% U. Av.	14% U. Av.	28% U. Av.	7% O. Av.	3% O. Av.	8% O. Av.	6% O. Av.	12% O. Av.	Av.	U. Av.
Oats	11% U. Av.	36% U. Av.	13% U. Av.	31% U. Av.	Av.	Av.	9% O. Av.	9% O. Av.	Av.	Av.	U. Av.
Corn Harvest began, average Date	201 (July 20)	201 (July 20)	208 (July 27)	208 (July 27)	212 (July 31)	218 (Aug. 6)	221 (Aug. 9)	227 (Aug. 15)	233 (Aug. 21)	213 (Aug. 1)	214 (Aug. 2)
Beans	U. Av.	Much U. Av.	Much U. Av.	Much U. Av.	U. Av.	U. Av.	O. Av.	U. Av.	..	Av.	U. Av.
Peas	U. Av.	Much U. Av.	U. Av.	U. Av.	U. Av.	Av.	..	Av.	..	O. Av.	U. Av.
Potatoes	O. Av.	U. Av.	Av.	U. Av.	U. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Turnips	U. Av.	U. Av.	U. Av.	U. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	Av.
Mangolds	U. Av.	Much U. Av.	U. Av.	Much U. Av.	O. Av.	U. Av.	O. Av.	..	..	O. Av.	U. Av.
Hay (Permanent Pastures)	48% U. A.	71% U. A.	62% U. A.	62% U. A.	35% U. A.	35% U. A.	2% U. A.	7% U. A.	47% U. A.	U. A.	Much U. A.
Hay (Clover, &c.)	33% U.A.	55% U.A.	46% U. A.	51% U. A.	37% U. A.	26% U. A.	3% O. A.	11% U. A.	37% U. A.	U. A.	Much U. A.

The variations from the average relating to Wheat, Barley, Oats and Hay have been obtained from the *Agricultural Produce Statistics* issued by the Board of Agriculture, but those for the other crops from Returns which appeared in the *Agricultural Gazette*.

TABLE VI.—Estimated Yield of Fruit Crops in 1893.

Description of Crop.	England. A. SW.	C. S.	D. Mid.	E. E.	F. NW.	I. NE.	Scotland. H. J. and K. W. E. and N.	Ireland. B. and G. S. & N.	British Isles.
Apples	O. Av.	Av.	Av.	Av.	Av.	Av.	Av.	O. Av.	Av.
Pears	Av.	U. Av.	U. Av.	Av.	U. Av.	U. Av.	U. Av.	Av.	U. Av.
Plums	O. Av.	Av.	O. Av.	O. Av.	Av.	O. Av.	Av.	Av.	Av.
Raspberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Currants	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Gooseberries	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.	O. Av.
Strawberries	Av.	U. Av.	U. Av.	U. Av.	Av.	U. Av.	Av.	U. Av.	U. Av.

Symbols:—O. = Over. U. = Under. Av. = Average. This Table has been compiled from Returns which appeared in the *Gardeners' Chronicle*.

TABLE VII.

APPROXIMATE VARIATIONS FROM THE AVERAGE IN MEAN TEMPERATURE, RAINFALL, AND SUNSHINE, 1892–93.

Winter 1892–93.

Temperature.

Months.	Eng. SW.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. NW.	Ire. N.	Scot. W.	Eng. N.E.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
December	−2·0	+0·3	−2·0	−3·0	−2·8	−2·5	−0·3	−2·0	−2·5	−3·0	−2·3
January	−3·8	−2·3	−5·0	−2·8	−4·5	−2·8	+1·5	−2·3	−2·5	−1·5	−3·0
February	+1·8	+1·0	+2·5	+2·0	+1·5	+1·8	+1·0	+1·3	+1·3	+1·0	+1·0
Winter ...	−1·3	−0·3	−1·5	−1·3	−1·9	−1·2	+0·7	−1·0	−1·2	−1·2	−1·4

Rain.

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
December	−2·3	−1·6	−1·6	−1·6	−1·3	−1·3	−1·0	−2·6	−1·4	−1·6	−1·9
January	−1·5	−0·8	−0·8	−0·7	0·0	−1·8	−1·0	−3·4	−0·6	−0·9	−1·0
February	+2·0	+1·3	+1·0	+0·9	+0·8	+1·2	+1·0	+1·1	+0·4	+0·4	+0·5
Winter	−1·8	−1·1	−1·4	−1·4	−0·5	−1·9	−1·0	−4·9	−1·6	−2·1	−2·4

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
December	+14	− 4	+19	+18	+13	+20	− 5	− 4	+19	+ 4	−11
January	+11	−15	− 8	0	− 8	− 5	+ 8	+10	− 1	−19	+ 5
February	− 6	− 4	+ 6	− 2	− 6	−12	−16	− 5	+ 3	− 6	− 4
Winter	+19	−23	+17	+16	−11	+ 3	−13	+ 1	+21	−21	−10

Spring 1893.

Temperature.

	°	°	°	°	°	°	°	°	°	°	°
March	+3·2	+2·6	+3·0	+3·2	+3·0	+2·8	+2·6	+2·0	+3·0	+2·2	+1·8
April	+5·8	+4·5	+4·5	+4·5	+3·0	+4·8	+4·3	+3·8	+1·8	+3·3	+3·3
May	+4·2	+4·0	+3·4	+3·6	+2·8	+3·6	+4·0	+3·4	+3·0	+3·2	+2·8
Spring	+4·4	+3·7	+3·6	+3·8	+2·9	+3·7	+3·6	+3·1	+2·6	+2·9	+2·6

Rain.

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
March	−2·1	−2·4	−1·0	−1·4	−1·0	−0·9	−1·1	−1·7	−0·7	−1·4	−0·5
April	−2·1	−1·5	−1·6	−1·4	−1·5	−1·4	−1·0	−1·1	−1·4	−0·9	−0·7
May	−1·1	−0·8	−1·3	−0·7	−1·2	−0·5	−0·8	−0·7	−0·5	−1·0	−0·9
Spring	−5·3	−4·7	−3·9	−3·5	−3·7	−2·8	−2·9	−3·5	−2·6	−3·3	−2·1

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
March	+ 70	+ 26	+ 91	+ 86	+84	+ 55	+17	+39	+ 65	+50	− 9
April	+ 98	+ 37	+115	+105	+95	+ 81	+30	+63	+ 90	+22	+ 8
May	+ 40	+ 40	+ 36	+ 24	+18	− 19	−63	−19	− 3	−34	−56
Spring	+208	+103	+242	+215	+197	+117	−16	+83	+152	+38	−57

+ indicates above the average, − below it.

TABLE VII.

VARIATIONS FROM THE AVERAGE—*Continued.*

Summer 1893.

Temperature.

Months.	Eng. SW.	Ire. S.	Eng. S.	Eng. Mid.	Eng. E.	Eng. NW.	Ire. N.	Scot. W.	Eng. NE.	Scot. E.	Scot. N.
	°	°	°	°	°	°	°	°	°	°	°
June	+3·3	+3·0	+2·8	+3·0	+1·8	+3·3	+3·5	+2·8	+1·8	+2·3	+2·5
July	+1·8	+1·5	+1·0	+1·3	+0·8	+1·8	+1·5	+1·0	−0·5	+0·3	+1·8
August	+3·0	+3·2	+2·8	+3·8	+2·6	+3·4	+3·0	+2·6	+3·4	+2·8	+2·4
Summer ..	+2·7	+2·6	+2·2	+2·7	+1·7	+2·8	+2·7	+2·1	+1·6	+1·8	+2·2

Rain.

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
June	−1·1	−0·8	−0·9	−1·1	−0·9	−0·4	−0·6	−1·5	−0·6	+0·6	−1·6
July	+1·8	−0·4	+1·2	+0·3	+0·2	+0·2	+0·5	+0·2	+0·4	−0·3	+0·4
August	−1·4	+0·3	−1·2	−1·0	−0·3	−0·6	+0·9	−0·6	−0·7	−0·4	+0·2
Summer ..	−0·7	−0·9	−0·9	−1·8	−1·0	−0·8	+0·8	−1·9	−0·9	−0·1	−1.0

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
June	+ 71	+16	+ 44	+36	+35	+36	+ 38	+36	+30	+ 1	+ 6
July	+ 1	− 6	+ 6	− 7	− 8	+ 1	+ 30	− 5	−12	−26	−27
August	+ 44	+41	+ 55	+58	+40	+39	+ 41	+44	+52	+23	−17
Summer ..	+116	+51	+105	+87	+67	+76	+109	+75	+70	− 2	−38

Autumn 1893.

Temperature.

	°	°	°	°	°	°	°	°	°	°	
September ..	+0·3	−0·3	0·0	+0·3	−1·3	+0·3	+0·3	−0·5	0·0	−0·8	−1·0
October	+1·3	0·0	+2·5	+2·5	+2·5	+2·0	+0·8	+1·3	+1·8	+1·8	+1·3
November	−2·2	−3·0	−2·2	−2·0	−1·4	−1·6	−1·6	−1·8	−1·0	−2·6	−3·2
Autumn ..	−0·2	−1·1	+0·1	+0·3	−0·1	+0·2	−0·2	−0·3	+0·3	−0·5	−1·0

Rain.

	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.	Ins.
September ..	−1·1	−1·0	−0·2	−1·5	−1·6	+0·6	−0·1	−1·0	−0·8	−0·6	+3·4
October	+0·6	−0·4	+1·1	−0·5	+0·2	+0·3	+0·3	+1·3	−1·2	−0·4	+3·0
November ...	−2·2	−2·0	−1·2	−1·5	+0·2	−1·4	−1·6	−2·4	−0·2	−0·5	+2·4
Autumn ..	−2·7	−3·4	−0·3	−3·5	−1·2	−0·5	−1·4	−2·1	−2·2	−1·5	+8·8

Sunshine.

	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.
September....	+13	+16	+17	+31	+19	+ 1	+23	+20	+34	+ 6	0
October	+ 3	+ 4	+21	+20	+26	+ 8	+ 4	+11	+43	+18	−36
November....	+26	+13	+18	+12	+13	+13	+31	+32	+18	+ 3	−13
Autumn....	+42	+33	+56	+63	+58	+22	+58	+63	+95	+27	−49

The above Table has been compiled from the variations from the mean given in the *Weekly Weather Reports* issued by the Meteorological Office.

Grass lands generally scorched and bare. Much late sown barley has not germinated, and turnips have come up and withered away. *Aberystwith* (A.). 31st Grass crop extremely thin and scanty. *Killarney* (B.). No real injury done here by drought. 21st. Peas and potatoes ready for eating. *Bembridge* (C.). 8th. Gathered ripe strawberries. Meadow and grass crops dried up, no prospect of any hay. Wheat crops suffering. Barley not half sown, and what has

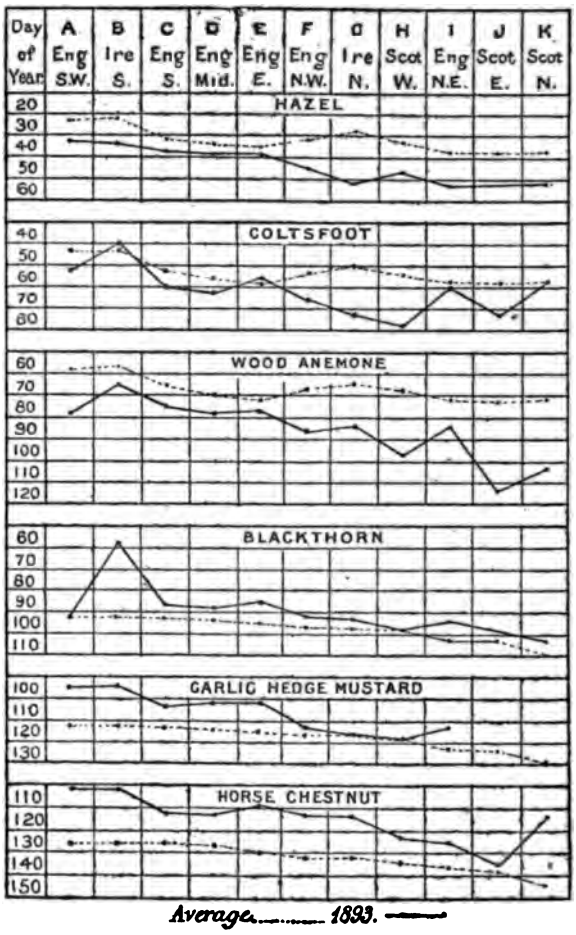


FIG. 1.—Mean Dates (Days of Year) of Flowering of the Plants in 1893, and also the Average Dates.

been sown remains dormant, as is the case with many other small seeds. *Buckhorn Weston* (C.). All flowering shrubs and trees have bloomed in an unusual degree while other plants have not been up to the average. A great scarcity of bird this season. 10th. Picked ripe strawberries. 15th. No food in the pasture for the cattle. *Pennington* (C.). 5th. Gathered a bunch of Maréchal Niel and Gloire de Dijon roses from a wall. 22nd. Commenced cutting permanent pasture grass, the worst crop ever known. *Strathfield Turgiss* (C.). Plants flowering abnormally early, but their growth greatly stunted. Migratory birds do not seem to have been affected by the unusual weather, indeed, some are later than the average. From the dryness of the weather, the mud using birds especially swallows, martins, and swifts, have had great difficulty in making

their nests, several falling from the non-coherence of the material employed. The late building thrushes and nuthatches also have been sore put to for "clay." *Lynsted* (C.). Owing to a wet February and drought following, a large acreage of land intended for spring corn has not been sown. *Farnborough* (C.). 20th. Strawberries sent to market, most unusually early for field grown fruit. *Swanley* (C.). Seeds germinate very slowly. *Bickley* (C.). Foliage on trees full and

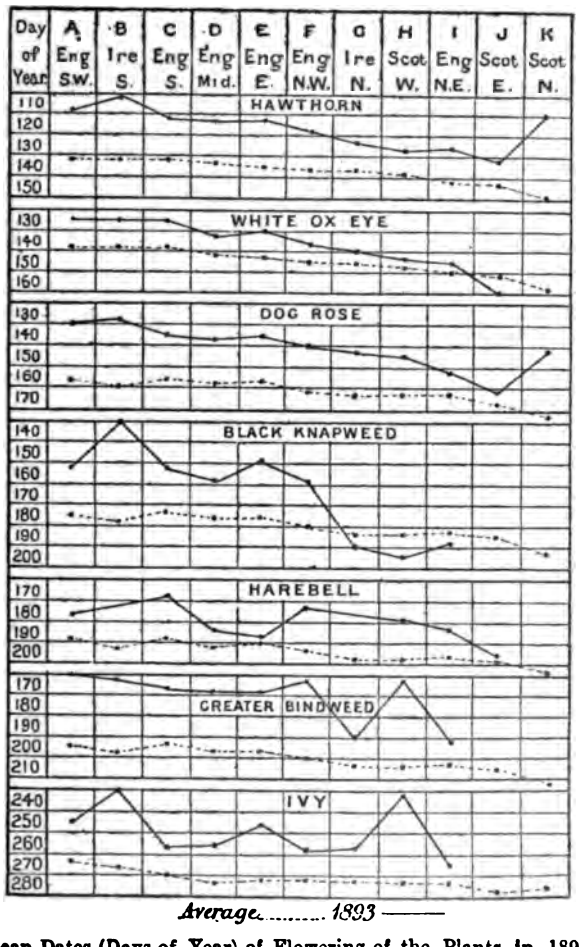


FIG. 2.—Mean Dates (Days of Year) of Flowering of the Plants in 1893, and also the Average Dates.

perfect, also flowers, especially horse-chestnuts. *Churt* (C.). 1st. May-fly seen. 30th. Dahlias damaged by frost, and in the lower portions of the parish the potato haulm was killed. 31st. The rise of the May-fly is now practically over. In many years it is hardly beginning at this date. *Orshott* (C.). Hardly any grass or vegetables, owing to the absence of rain. Wheat ears fully formed by end of month. *Ashtead* (C.). Young seedling trees, especially beech, killed by drought. At end of month there were a number of bright red and brown shoots to be seen on the oak, maple, dogwood, &c., reminding one of the so-called "lammas shoots" usually seen in August. *Addlestone* (C.). Seeds sown did not germinate owing to dryness of soil. 30th and 31st. Potatoes blackened by frost. Grasses, corn, &c., flowering prematurely and very short in the stalk.

East Molesey (C.). 15th. Trees and shrubs none the worse for the long drought, but small plants drooping and grass dried up. *Farley* (C.). Crops much injured by drought, particularly the grass. 7th. Gloire de Dijon and Maréchal Niel roses in bloom. Hawthorn in full beauty before May 1st. 31st. Potatoes injured by frost. *Marlborough* (C.). Common yellow toadflax (Linaria vulgaris) 44 days in advance of its average time, and the earliest yet observed. *Reading* (C.). The hay off three fair sized meadows was loaded on one cart. *Oxford* (D.). 15th. Dog rose in flower 15 days earlier than the previous earliest date, May 30th, 1880. *Cheltenham* (D.). Very fine show of blossom on fruit trees, but cold nights and drought prevented much of it setting. Flowers of cowslips, buttercups, ox-eye daisies, &c., stunted and small, but trees and shrubs, the roots of which go down deeper, blossomed splendidly. *Beckford* (D.). The foliage of the woods is magnificent, and there is a grand show of blossom on the fruit trees. Some of the field grasses not worth cutting. 20th. Strawberries ripe. 29th. Red currants ripe. *Watford* (D.) Few wild flowers to be met with. Many bullfinches in the garden, which is unusual for Watford. *Broxbourne* (D.). Never saw the blossom on the apple, pear, peach, plum trees, &c., finer or more abundant. *St. Albans* (D.). Foliage scanty, blossom abundant. *Berkhamsted* (D.). 10th. A wild dog rose in blossom, 31 days earlier than the average for the previous seven years. *Evesham* (D.). The first crop of peas almost a failure. One farmer got nothing but fodder for his cattle from 30 acres. Many fields sheets of white ox-eye, in exceptional abundance, but undersized. *Northampton* (D.). Pastures dried up. Plants flowered extremely early, but the blossom did not last long. Caterpillars were very destructive to foliage. *Burbage* (D.). Low growing vegetation has suffered severely from the drought, but the trees, with the exception of some caterpillar and aphis attacks, have thriven remarkably well. Grass keeps dreadfully short. Clover leys, strange to say, have wonderful crops with some plants 3 ft. high. 29th. First green gooseberries picked for market, 28 days earlier than in 1892. 30th and 31st. Runner beans and potatoes blackened by frost. *Thurcaston* (D.). First blossom out on hawthorn on April 19th, and out of flower on May 19th. *Walsall* (D.). 20th. No grass. Lawns scorched into brown and bare patches. *Tean* (D.). The grass has not suffered much from the drought here. Indeed, the farmers expect a specially good hay crop. *Beeston* (D.). 8th. Lawns burnt brown as in summer. *Hodsock* (D.). 8th. Gathered a dish of strawberries. *Bakewell* (D.). 31st. Vegetation has not suffered much from the recent drought. Outlook for crops fairly hopeful. *Macclesfield* (D.). Have not suffered much from drought here. Blight and caterpillars have almost stripped the apple trees of leaves. 1st. Most forest trees in full foliage. *Belton* (D.). Grass parched, and in places killed by drought. Strawberries ripe. *Hitchin* (E.). 2nd. Landrail heard. *Lexden* (E.). We are feeding blackbirds and thrushes the same as in a hard frost, as they could get nothing off the lawn. *Sproughton* (E.). Absolutely no grass, not even on the water meadows. *Wryde* (E.). 9th. Finished sowing barley. Very little came up at all until July, and never came to maturity, owing to dry weather. 25th. Ploughed up beans sown in February, they were not more than 6 ins. high. 31st. Pastures appear baked up, with grass dying. Some spring corn has remained in the ground nearly two months, and is as dry as when put in. *Penmaenmawr* (F.). 16th. Strawberries ripe. 28th. Hay a very short crop. *Ambleside* (F.). An early season with short spring growths—hay, trees, &c. *Orry's Dale* (F.). The lilac has flowered in unusual profusion. *Edgeworthstown* (G.). 31st. The rainfall has been very light, all crops, however, are in a wonderfully flourishing and forward state, some meadows being so heavy already that a shower of rain quite laid them. *Loughbrickland* (G.). The spring abnormally fine and dry. Butterflies scarce. *Londonderry* (G). The farmers say they never remember so favourable a season. Drought generally, but occasional copious timely showers. *Ballynagard* (G.). Very hot and dry season, with very occasional rain, which saved the crops. *Tynron* (H.). Never before recollect seeing roses, brambles, and fox-gloves in bloom in May. *Thornhill* (H.). No injuries from drought, abundance of grass in the pastures. 31st. Two species of heather in bloom. *Jardington* (H.). Grass abundant. Drought not injurious here. *Doddington* (I.). 31st. No grass owing to the drought, and pastures as dry and burnt up as in August. *Driffield* (I.). 11th. Potatoes blackened by frost. 28th.

First strawberry gathered. *Durham* (I.). Grass improved rapidly after the rains of the 17th. Swallows and swifts plentiful. 5th. Swift first seen. *Low Fell* (I.), Gloire de Dijon rose in flower during the last week. *Cambois* (I.). Oats and hay the only crops injured by drought. *Aberdeen* (I.). One of the driest springs on record, but favourable for preparing ground for seeds. Crops, both field and garden, except hay, most promising. Swallow and cuckoo arrived unusually early. *Inverbroom* (K.). This has been the best spring known for many years, plenty of rains and damp mists. An abnormal quantity of wasps, green fly, caterpillars, &c.

JUNE.—*Marazion* (A.). Strawberry plants produced little or no fruit, owing to drought. *Killarney* (B.). The greater bindweed bloomed 28 days earlier than its average date for the previous 10 years. *Bembridge* (C.). Began cutting meadow hay, very light crop, and carted the next day. *Pennington* (C.). At the end of the month gardeners busy sweeping up leaves. 7th. Haymaking over, sadly deficient crop, 4 tons only carried where 45 tons have been secured in good seasons. 19th. Leaves on limes and planes changing colour and falling fast. *Bidborough* (C.). Black currants have shrivelled and dropped off the bushes owing to drought. *Swanley* (C.). 5th. Ripe cherries sent to market. 12th. Raspberries sent to market. 14th. Black currants sent to market. *Churt* (C.). Owing to the drought, plants flowered abundantly, but very early, and blossoms small. When picked they soon withered. *Addlestone* (C.). Many fruit trees, &c. killed by drought. *Whatley* (C.). Towards the end of the month birds were found dying in the fields for want of food. *Beckford* (D.). 12th. Some meadows mown for hay, others not till August 15th, and many not at all. *Watford* (D.). Grass dried up, cutting the green barley for cattle. *Harpenden* (D.). 2nd. First wheatear observed out of the sheath, this is exceptionally early. In Sir J. B. Lawes' grass experiments at Rothamsted, the plot which never receives any manure yielded 3 cwt. of hay per acre, instead of its usual average of 21 cwt.; and the plot the most heavily manured yielded 28 cwt. per acre, instead of an average of 57 cwt. *Ross* (D.). 8th. Black currants ripe for use. *Burbage* (D.) Grazing pastures a pitiable sight. *Thurcaston* (D.). Hay crop ridiculously small. Flowers over almost as soon as open. *Tean* (D.). 8th. First hay cut. *Hodsock* (D.). 16th. Grass very burnt. *Harrogate* (D.). 18th. Haymaking began, but crops exceedingly light. 21st. Numerous nests of wasps and hornets. *Lexden* (E.). No hay to be cut, the pastures being all dried up and burnt, and no fodder for sheep and stock. *Penmaenmawr* (F.). 15th. Hay harvest began, very thin crops. *Claughton* (F.). 30th. Hay cut. *Tynron* (H.). 2nd. Since recent copious rains the country is looking extremely verdant. *Driffield* (I.). 3rd. Gathered first ¼ lb. of strawberries, 32 days earlier than in 1886. 20th. Remarkable profusion of wild rose bloom. *Thirsk* (I.). 20th. Haymaking began. *Low Fell* (I.). Cuckoo and corncrake scarce this year. *Inverbroom* (K.). Wasps, house flies, bluebottle, &c. very numerous.

JULY.—*Falmouth* (A.). Blackberries ripe at end of July, and unusually fine and plentiful. *Killarney* (B.). Mushrooms and wasps in unusual quantity. 27th. Hollyberries red in many places. *Bembridge* (C.). 4th. Clouded-yellow butterflies very abundant. *Buckhorn Weston* (C.). Great numbers of ladybirds, which are rarely seen here at all. *Pennington* (C.). Mushrooms very plentiful for a fortnight in the middle of the month. Wasps a great plague (140 nests destroyed at one place only), and did much injury to cherries, plums, and pears. *Swanley* (C.) 1st. Red and white currants sent to market. 3rd. Early potatoes and apples sent to market. 24th. Plums sent to market. *Addlestone* (C.). Wasps very troublesome. *Whatley* (C.). Butterflies very scarce, notably the small copper. Have seen humming bird moths three times. An enormous number of wasp's nests. *Cheltenham* (D.). The rains rapidly restored the pastures, and a small second crop of hay was well secured. *Beckford* (D.). Began cutting wheat. *Watford* (D.). Birds devoured all our peas, crop after crop. Wasps very abundant. *Berkhamsted* (D.). 4th. When digging up some potatoes in my garden, the ground in which they were growing was found to be dust dry to the depth of 17 ins. *Harpenden* (D.). The seeds of most root crops were in the ground several weeks before they germinated at all, and even after germination the plants made but little growth, until the rains of July moistened the hardened soil. *Walsall* (D.). 11th. Young lime, beech, and elm trees quite

leafless. Some trees show autumn tints, and the leaves are rapidly falling through drought. 30th. Most trees quite recovered, and have a spring-like appearance. Apple trees with second blossoms on them. *Tean* (D.). After the thunderstorm of the 3rd grass grew rapidly. 26th. Blackberry ripe. *Hodsock* (D.). At end of month grass very green, quite like spring. 26th. Harvest began. *Harrogate* (D.). 8th. Terrible thunder and hailstorm. Some of the large pieces of ice which fell weighed over an ounce. About half the corn crops destroyed, also potato tops. Large slices cut off many apples by the sharp pieces of ice, without bringing the fruit from the trees. *Bocking* (E.). At the beginning of the month the grass was much burnt up and browned, but rapidly recovered in a week or two. *Lexden* (E.). 1st. Lime trees shedding their leaves. *Tacolneston* (E.). Wasps extremely numerous. Apples an enormous crop, and very fine and good. 28th. First wheat and oats cut. *Egremont* (F.). Wasps very numerous. *Jardington* (H.) 28th. Harvest began. *Helensburgh* (H). 28th. Barley in the stook. *Driffield* (I.). 12th. Wasps very plentiful. *Thirsk* (I.). 20th. Harvest began, and was over in about a fortnight. *Lilliesleaf* (I.). Flycatchers unusually numerous. 29th. Wasps very numerous.

AUGUST.—*Marazion* (A.). Saw some specimens of the clouded-yellow butterfly. *Long Ashton* (A.). 24th. There are sweet peas in our garden blossoming from self-sown seed. *St. David's* (A.). Great scarcity of grass, and stock selling at nominal prices. *Bembridge* (C.) 24th. More clouded-yellow butterflies. Wasps very numerous. *Pennington* (C.). Harvest commenced June 27th, but not over by the end of this month, owing to late sown spring oats and barley not coming on from scarcity of rain. 3rd. Althea Frutex in flower 77 days earlier than in 1892. 10th. Last swift. *Swanley* (C.). 3rd. All corn on farm carried. 18th. Damsons sent to market. *Chislehurst* (C.). 13th. Elms and limes quite yellow, and a great quantity of leaves have already fallen. *Churt* (C.) Grass growing rapidly since the rains. *Oxshott* (C.). Garden produce almost *nil* throughout the summer. Quite a plague of wasps and flies. *Addlestone* (C.) 17th. Fruit crops much injured by wasps. Lawns again brown and bare. *East Molesey* (C.). Grass, which had revived, now worse than ever. Wasps not unusually plentiful. *Whatley* (C.). 28th. Wasps have been very numerous the last few days. Small copper butterfly quite common, but no painted-ladies. 30th. Humming-bird moth numerous. *Oxford* (D.). Wasps almost a plague. *Cheltenham* (D.). Pastures again brown, and the trees are shedding their leaves. Vegetables very scarce. *Beckford* (D.). 30th. Pastures brown and grass dried up. Pools and water courses dry which were never known to fail before. *Berkhamsted* (D.). 1st. Until to-day no measurable quantity of rain water has come through the 2½ ft. of soil in my percolation gauges since March 12th, or for 20 consecutive weeks. *Ross* (D.). Wasps not extraordinarily numerous, less so than in 1846. *Walsall* (D.). Saw several meadow brown butterflies in the garden—first time during eight years. *Hodsock* (D.) By beginning of month hawthorn berries were already red. *Harrogate* (D.). Harvest practically over. *Bocking* (E.). For about a week in the middle of the month there was a perfect plague of wasps. Butterflies not more numerous than usual. *Wryde* (E.). 2nd. Began harvest. 30th. Finished harvest. The worst on record, and no straw for winter use. *Penmaenmawr* (F.). Good crops of corn well harvested. 25th. Cutting second crop of meadow hay. *Giggleswick* (F.). Such a good year for gardens has not been known before in this district. *Edgeworthstown* (G.). No plague of wasps here. *Antrim* (G.). Leaves began to fall early in the month. Butterflies numerous, but no plague of wasps. *Ballynagard* (G.). Butterflies unusually numerous. Crops generally good. *Tynron* (H.). 8th. Wild raspberries nearly over. Mountain ash berries ripe. The drought has not injured the crops. *Driffield* (I.). 4th. Harvest began, or 27 days earlier than in 1891. 13th. Wasps unusually abundant this season. 21st. Trees permanently dropping their leaves. Foliage thin throughout the summer. 31st. Everything injured more or less by dry state of the soil. *Durham* (I.). The second blossoming of flowers was common. Summer flowers and foliage luxuriant, but the blooms lasted no time, and the leaves fell much earlier than usual. *Low Fell* (I.). Wasps very numerous. *Cambois* (I.). More wasps than usual. Potatoes a good and heavy crop.

SEPTEMBER.—*Marazion* (A.). Strawberries produced a considerable quantity of ripe fruit. *Mawnan Smith* (A.). 23rd Gathered two ripe wild strawberries.

St. Arvan's (A.). 24th. Grass lands dried up. *St. David's* (A.). The long drought did not damage wheat crop, nor potatoes and turnips. *Killarney* (B.). 15th. Delphiniums, perennials, phloxes, apples, bay, horse-chestnut, and dog rose flowering a second time. Horse-chestnuts quite ripe. 21st Laburnum in flower (three specimens sent). *Bembridge* (C.). Many trees and shrubs, the shoots of which had become ripened and rested during the hot weather, were started into growth again by the recent rains. Many apple and pear trees flowered. A syringa grandiflora blossomed from this year's wood. Mushrooms very plentiful. Carrots, beets, and onions a complete failure, owing to seed not germinating when sown. 24th. Wasps very numerous. *Buckhorn Weston* (C.). The wild roses, and also Scotch roses, are blooming again, while the dog-wood is in full blossom, with ripe berries. *Pennington* (C.). Hips, haws, and acorns very plentiful. An apple tree with several blooms on it. *Strathfield Turgiss* (C.). Scarcity of wild flowers, nearly all having bloomed so much earlier than usual, seed pods taking the place of blossoms. Many plants have blossomed twice, and even thrice, *e.g.* dog-wood. Butterflies have been very numerous. More acorns on the oaks than I have ever seen before. *Chislehurst* (C.). A great quantity of humming bird moths. *Cranleigh* (C.). 5th. Gathered strawberries from old plants. Apples small owing to drought. *Addlestone* (C.). 26th. Second crop of strawberries ripe. 30th. Red-admiral butterflies abundant. *Farley* (C.). 23rd. Dahlias killed by frost. *Salisbury* (C.). Wild fruits unusually abundant. The cornel was nearly as fully in flower as in spring. 26th. Dog rose in flower again. *Cheltenham* (D.). By the end of the month the foliage of most trees had become very thin. *Watford* (D.). Pastures very dry. Very few flowers in the garden, soil so dry and parched. *St. Albans* (*The Grange*) (D.). Many more species than usual flowered a second time. Wild roses and dog-wood bearing blossoms and mature fruit together. Never before remember comfrey flowering so freely as it has done this autumn. *St. Albans* (*Addiscombe Lodge*) (D.). 9th. Dog rose again in flower *Breinton* (D.). 20th. Leaves already falling, and meadows on gravel soil brown and bare. *Walsall* (D.). 1st. Last field of wheat carried. 9th. Acorns and sloes more abundant than the oldest inhabitant remembers. 21st. Saw perfectly leafless laburnums covered with blossom. 23rd. Trees half bare. Lovely autumn tints. 30th. Ripe strawberries gathered. 31st. Dahlias killed. *Tean* (D.). 5th. A third crop of hay was cut from the same field that was first mown on June 8th. 16th. Wild rose in flower again. *Macclesfield* (D.). 1st. Lime trees losing their leaves. 30th. The same trees a mass of golden foliage, though many leaves have fallen. *Harrogate* (D.). 3rd. Great mullein, foxglove, cowberry, laburnum, privet, clematis, and snowberry are flowering a second time. 17th. Enormous quantities of acorns are now fully ripe. 25th. Wild roses blooming at 500 ft. above sea-level. *Bocking* (E.). 3rd. Grass beginning to look brown again. *Sproughton* (E.). A peculiarity of the universally observed plague of wasps was their sudden and almost total disappearance about the middle of the month. *Ambleside* (F.). Many flowers have blossomed a second time. *Cronkbourne* (F.). 15th. Ripe strawberries gathered, and laburnum in bloom. *Saintfield* (G.). Some blackberries which have ripened their fruit are in flower again. Apples, &c. also in blossom. *Antrim* (G.). Strawberries bloomed a second time, and a few raspberries ripened. Never remember so many fine apples, or so many small ones. *Driffield* (I.). Birds attacking apples, owing to dry weather. Great crop of wild rose hips. *East Layton* (I.). 8th. Very severe hailstorm, grouse and partridges killed by the hailstones. Swallows have been unusually numerous. *Aberdeen* (J.). Crops of all kinds came early to maturity, and were secured in excellent condition, with good straw and very heavy grain.

OCTOBER.—*Mawnan Smith* (A.). 2nd. Some birches and sycamores bare of leaves. 4th. Hollies thick with berries. All berries plentiful and fine. 19th. Dog roses in flower. 27th. Hazel in flower. *Falmouth* (A.). Raspberries and strawberries have yielded a good crop. Raspberries 10d. a quart in the market. *Tiverton* (A.). Immense quantities of apples, pears, plums, and nuts this year. Raspberries for sale in the market during the month ending October 25th. On that day I bought them at 6d. a pound, and good flavoured. 2nd. Privet, dog-wood, and field rose in flower. 31st. Saw a field gay with poppies. *Instow* (A.). 31st. Gathered two or three dozen ripe raspberries of good flavour. Holly

berries exceptionally abundant this year. *St. Arvan's* (A.). Horse and Spanish chestnuts and acorns abundant. 22nd. Gathered ripe raspberries. 31st. Dahlias killed. *St. David's* (A.). Apple trees bloomed a second time, and fruit was formed. Mushrooms abundant. All the meadows fresh and verdant. *Aberystwith* (A.). 11th. Spanish chestnuts have ripened their fruit, which is unusual here. *Pennington* (C.). The late leaf shedding trees, such as oaks, beeches, and sycamores, retained their leaves well, and their autumn tints were fine. Jerusalem artichokes flowered. 7th. Dog rose and guelder roses again in flower. *Chislehurst* (C.). 14th. Several ripe strawberries. *Coneyhurst* (C.). 10th. Sand martins last seen. *Churt* (C.). Exceptionally heavy crop of pears, and fruit fine. Many apples very large, one weighed 19 ozs. Some young seedling dahlias have come up out of doors from the droppings of this year's seeds. 31st. Dahlias killed by frost. *Addlestone* (C.). 29th. Runner beans killed. *Cheltenham* (D.). Very few autumn wild flowers except poppies, which bloomed freely up to the end of the month. Berries very plentiful. *Watford* (D.). Poppies and charlock in full bloom. *St. Albans* (*Addiscombe Lodge*) (D.). Several flowers noticed on a guelder rose bush. *Ross* (D.). Second leafage noticed on larches. 14th. Horse-chestnut in blossom. *Hodsock* (D.). Autumn colouring of trees very fine by the middle of the month, but some trees bare. 30th. Dahlias killed. *Macclesfield* (D.). 1st. Horse-chestnut almost bare of leaves. *Harrogate* (D.). 5th. Rhododendrons flowering a second time. 10th. Mushrooms again abundant. *Hertford* (E.). The cornel has had a second crop of flowers, also dog and field roses. Sloe bushes seem especially to have suffered from the drought, from many the leaves are falling. *Tacolneston* (E.). Many plants flowered a second time, for instance a group of wild water lilies; wild roses also flowered in places. *Antrim* (G.). 17th. A wild rose in blossom. *Ballynagard* (G.). 15th. Dog roses and strawberries in bloom. 27th. White ox-eye again in flower. *Thirsk* (I.). Autumn tints unusually fine. 22nd. Gathered a wild rose. *Durham* (I.). 31st. Dahlias killed by frost. *Cambois* (I.). Hawthorn in bloom, and a second crop of strawberries gathered.

NOVEMBER.—*St. Arvan's* (A.). 12th. Many springs not known to fail before have become dry. *St. David's* (A.). The heavy gales brought a large deposit of salt to the lands, which destroyed much grass and seriously damaged rape and turnips. *Aberystwith* (A.). 5th. Daphne mezereum in flower. *Bembridge* (C.). 11th. Clouded-yellow butterfly seen. *Pennington* (C.). Oak leaves still holding on in many places at the end of month. Springs and wells remarkably low. *Chislehurst* (C.). 5th. Several ripe raspberries. *Oxshott* (C.). The grass never recovered from the drought, most fields still yellow instead of green. *Addlestone* (C.). 30th. Oaks and beeches retained their leaves longer than usual. Fine autumn tints. *Cheltenham* (D.). Apples and pears seem to have ripened too hurriedly, and are rotting very fast instead of keeping —many rotted on the trees. *Edgeworthstown* (D.). 1st. Laburnum in bloom. *Helensburgh* (H.). 17th. Numbers of trees blown down during the gale. *Driffield* (I.). 15th. Springs lower now than for 40 years. *Inverbroom* (K.). The most stormy and windy autumn ever remembered.

DISCUSSION.

THE PRESIDENT (Mr. R. Inwards) said that probably very few persons had any idea of the amount of correspondence and information which had to be dealt with in the preparation of this report, and the thanks of the Society were due to Mr. Mawley for the labour bestowed in its compilation, and also to the observers who had supplied the necessary material.

Mr. H. SOUTHALL said that Mr. Mawley's report dealt so fully with the remarkable season of 1893, that there was hardly room to add anything to so clear and complete a summary. His own experience of the effects of the weather of 1893 on the plants, chiefly herbaceous, in his garden, very closely corresponded with what was described in the report. A striking feature in the phenology of last year was the remarkably quick flowering of plants after the break up of the frost of January. Cyclamen coum was the first to appear in bloom, although this was by no means considered to be a hardy plant, but the frost destroyed many plants usually regarded as of a hardy character, and was

especially fatal to plants coming from the Cape of Good Hope. People had said that the abundance of flowers in spring would result in a scarcity of summer blossoms, but his own experience was quite contrary to this statement, there being a continuous succession of flowers throughout the season. The drought appeared to have seriously affected evergreens, especially those varieties which were shallow-rooted, and probably the injurious effects of the abnormal dryness was not yet fully known, but on the whole the effect of the weather of 1893 upon horticulture would, he thought, prove to be beneficial. It was a great advantage to have accurate accounts of the effects of atmospheric conditions upon phenological phenomena, and Mr. Mawley's report supplied such information.

Mr. F. J. BRODIE said that mention had been made in the report of a second drought in August, but he was not aware that any drought prevailed at that time. Was this dry period a "drought" according to Mr. Symons' definition?

Mr. C. HARDING bore testimony to the valuable information to be gleaned from Mr. Mawley's reports, and said that the weather in the various districts often differed considerably; and the year 1893 had been no exception in this respect, for while in the south-eastern districts, the year had, with the single exception of 1868, been the driest on record, the west of Scotland had experienced the wettest year, excepting one, ever known. Considered horticulturally, last year (1893) was undoubtedly exceptional, but the present year (1894) promised to be more remarkable still, for fruit trees and vegetation in general were fully a month in advance of their average condition at this early period of the year.

Mr. F. C. BAYARD thought that the wet weather of February might have influenced the flowering of the hazel and caused it to be later than the average.

Mr. E. MAWLEY, in reply, said that in speaking of the dry weather of August as the "August drought" he was describing it as a horticulturist rather than a meteorologist, for although it may not have been a drought according to the definitions adopted by Mr. Symons, it seriously affected vegetation. The destruction to certain plants caused by the winter of 1892-3 was somewhat remarkable, all the montbretias and globe artichokes which had remained in his garden uninjured for eight years, and which were unprotected except to the extent of a little "earthing up," having been killed. The dates of flowering of the hazel may have been retarded by the wetness of February, but the dulness of the month probably exerted a greater influence in causing the blossoming to be later than usual. The greatest satisfaction he had felt in preparing this report was concerning the curves of average flowering, which for many of the plants are even smoother than in the two previous years.

TEMPERATURE, RAINFALL, AND SUNSHINE, AS RECORDED DURING THE PAST FIVE YEARS AT LAS PALMAS, GRAND CANARY.

By J. CLEASBY TAYLOR, M.D.

(Plate III.)

[Received October 17th, 1893—Read February 21st, 1894.]

The islands of the Canary Archipelago are almost entirely situated between the 28th and 29th degrees north of the Equator, so that difference of latitude does not enter into any of the questions relating to the various climates of the group.

It is different with the longitude, as the islands extend over five degrees; the most eastern islands being within 60 miles of the African coast, whilst the western are 300 miles away. This fact modifies the aspect, climate, flora, crops, etc., making the eastern part of the group African, and the western part Atlantic in character.

In addition to this general factor there are local ones affecting different localities. These are the position and height of the mountains; the northern slopes experiencing more cloudy weather and greater rainfall than the southern. This is more noticeable in those islands in which the mountainous ridges rise quickly to a great altitude.

The island of Grand Canary occupies a position midway between the African Continent and the most western islands. (Plate III.) The mountain peaks rise to a little over 6,000 feet, and they are about 20 miles from the litoral (in a horizontal line). For this latter reason the litoral is somewhat free from the influence of the mountains. And from its position the chief town and port of the island, Las Palmas, is particularly free. The town is exposed from north-west, through north and east to south, and sheltered from the south-

TABLE I.—Mean Maximum and Mean Minimum Shade Temperatures.

Months.	Mean Maximum.							Mean Minimum.						
	1888.	1889.	1890.	1891.	1892.	1893.	Mean.	1888.	1889.	1890.	1891.	1892.	1893.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January ..	..	65·2	67·0	65·2	68·5	68·5	66·9	..	57·4	57·5	57·0	58·7	58·6	57·8
February ..	..	66·2	66·9	67·1	70·2	70·0	68·1	..	57·8	57·8	56·2	60·0	57·9	57·9
March	..	66·7	64·7	69·9	69·6	70·8	68·3	..	59·5	57·6	58·3	58·7	60·3	58·9
April	..	65·8	67·8	71·0	70·5	70·8	69·2	..	58·8	60·1	60·6	59·6	61·0	60·0
May	..	69·7	69·4	70·7	72·0	73·6	71·1	..	62·1	63·0	62·8	63·0	63·6	62·9
June	..	..	72·0	74·6	74·3	76·1	74·2	..	..	65·4	66·8	66·2	68·5	66·8
July	..	..	72·2	78·1	78·0	78·0	76·6	..	..	66·5	70·0	70·0	71·0	69·4
August	..	..	..	80·0	78·5	81·1	79·8	..	..	..	69·6	70·8	72·5	71·0
September	..	..	76·3	78·0	78·8	80·6	78·4	..	..	67·8	68·0	69·3	71·4	69·0
October	78·0	73·0	75·8	76·2	76·9	80·0	76·6	67·7	65·3	67·3	67·4	66·6	68·5	66·8
November ..	72·8	71·5	71·2	71·8	73·2	75·0	72·6	63·6	63·3	62·8	62·7	63·8	64·8	63·2
December ..	68·7	66·8	67·3	70·7	70·3	70·9	69·1	60·8	58·6	58·1	61·0	60·2	61·7	59·7

TABLE II.—Absolute Maximum and Absolute Minimum Shade Temperatures.

Months.	Absolute Maximum.						Absolute Minimum.					
	1888.	1889.	1890.	1891.	1892.	1893.	1888.	1889.	1890.	1891.	1892.	1893.
	°	°	°	°	°	°	°	°	°	°	°	°
January	..	67·5	71·0	71·0	78·5	73·5	..	55·0	54·5	51·5	56·5	51·5
February	..	72·5	74·5	71·0	75·5	73·5	..	54·5	53·5	52·0	57·0	55·0
March	..	72·0	72·0	75·0	82·0	81·5	..	56·5	51·5	54·5	55·0	55·0
April	..	69·0	71·5	82·0	76·5	74·0	..	53·5	56·0	58·5	56·0	55·0
May	..	77·0	80·0	80·0	77·0	78·0	..	58·0	57·0	59·5	56·5	59·0
June	..	..	81·5	77·5	77·5	81·5	..	..	61·5	64·5	61·0	65·0
July	..	..	76·0	83·0	81·5	80·5	..	..	64·5	67·5	67·5	68·5
August	..	..	..	85·5	82·0	85·5	..	..	..	67·5	68·5	68·0
September	..	..	82·5	81·0	80·0	85·0	..	..	65·5	66·0	65·0	68·0
October	85·5	77·5	80·0	81·5	80·5	95·0[1]	62·5	58·0	65·0	63·0	63·5	65·0
November	75·5	74·5	74·5	79·5	77·5	82·0	58·5	61·5	58·0	58·0	59·5	58·0
December	73·5	70·5	72·5	76·0	76·0	81·5	57·0	52·5	53·5	57·5	55·0	55·0

[1] South Wind.

TABLE III.—Air and Sea Temperature.

Months.	Mean Air Temperature. (Mean of Max. and Min.)							Mean Sea Temperature at Noon. (3 feet below Surface.)						
	1888.	1889.	1890.	1891.	1892.	1893.	Mean.	1888.	1889.	1890.	1891.	1892.	1893.	Mean.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January ..	..	61·3	62·2	61·1	63·6	63·5	62·3	..	66·7	64·1	64·2	66·6	66·9	65·7
February ..	..	62·1	62·7	61·7	65·1	63·9	63·0	..	65·0	63·9	63·9	66·0	66·5	65·1
March ...	..	63·7	61·1	64·3	64·1	65·2	63·7	..	65·8	63·3	65·2	66·0	66·8	65·4
April	..	62·8	62·0	65·8	65·0	65·9	64·6	..	64·6	64·5	66·5	66·6	67·6	65·9
May	..	65·9	66·2	66·7	67·5	68·6	66·5	..	66·7	65·4	67·8	67·1	69·4	67·3
June	..	..	68·7	70·7	70·2	72·3	70·5	..	..	68·1	69·9	69·9	71·4	69·8
July	..	..	69·3	74·0	74·0	74·5	73·0	..	..	70·0	73·0	72·1	73·0	72·0
August	..	..	..	74·3	74·6	76·8	75·4	..	..	71·6	74·3	72·8	74·8	73·4
September..	..	..	71·2	73·0	74·0	76·0	73·8	..	..	72·1	74·5	73·5	76·4	74·1
October	72·8	69·1	71·5	71·8	71·7	74·2	71·8	72·8	70·3	72·7	73·0	73·5	74·4	72·8
November ..	68·2	67·3	67·0	67·3	68·5	69·9	68·0	70·1	69·9	69·6	70·7	70·5	71·6	70·6
December ..	64·7	62·7	62·7	65·8	65·2	66·3	64·6	68·7	66·0	66·9	68·2	67·8	67·8	67·6

TABLE IV.—Rainfall.

Months.	Total Rainfall.							Greatest Rainfall in 24 hours.					
	1888.	1889.	1890.	1891.	1892.	1893.	Mean.	1888.	1889.	1890.	1891.	1892.	1893.
	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
January	..	1·875	·330	·565	2·205	3·430	1·681	..	·435	·160	·200	·880	2·220
February	..	·775	·630	·917	·405	·155	·576	..	·190	·360	·435	·240	·130
March ..	..	·150	2·870	·225	·140	·575	·792	..	·060	·840	·090	·120	·120
April	..	·332	·030	·200	1·060	·395	·404	..	·200	·030	·070	·600	·150
May	..	·250	1·100	·130	·230	·020	·346	..	·080	·970	·070	·190	·020
June	..	..	·000	·000	·110	·030	·035	..	..	·000	·000	·060	·020
July	..	..	·000	·100	·000	·120	·055	..	..	·000	·100	·000	·100
August ..	..	..	·000	·002	·000	·050	·013	..	..	·000	·002	·000	·050
September	..	..	·050	·010	·577	·285	·232	..	..	·040	·010	·577	·100
October ..	·055	1·340	3·000	·500	·425	·380	·950	·045	·745	2·070	·285	·225	·200
November	1·105	1·465	2·660	2·465	1·070	1·065	1·638	·305	·630	1·580	·700	·430	·430
December	1·575	2·545	2·235	·230	1·305	3·245	1·856	·345	·740	·290	·080	·255	1·165

TABLE V.—Sunshine (Jordan Recorder.)

Months.	Total Sunshine.							Percentage of Possible Duration.						
	1888.	1889.	1890.	1891.	1892.	1893.	Mean.	1888.	1889.	1890.	1891.	1892.	1893.	Mean.
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	%	%	%	%	%	%	%
January ..	..	137	203	153	171	178	168	..	43·4	62·0	47·0	52·4	54·4	51·9
February ..	..	167	161	210	187	194	183	..	53·1	51·2	66·8	59·2	62·1	57·7
March	..	193	135	237	172	211	189	..	52·0	36·5	64·0	49·9	56·7	51·6
April	..	140	186	220	198	209	190	..	36·5	48·7	57·8	51·6	54·6	49·9
May	..	212	195	204	256	223	218	..	50·6	46·8	48·6	60·2	53·4	51·9
June	..	..	172	238	171	252	208	..	..	41·0	56·4	40·2	60·3	49·5
July	..	..	109	227	208	145	172	..	..	25·4	53·3	48·7	34·1	40·4
August	..	..	..	214	166	214	198	..	..	..	52·7	38·8	52·6	48·0
September	..	..	196	203	214	215	207	..	..	53·0	54·6	57·8	57·8	55·8
October	..	154	164	167	200	187	174	..	43·7	46·5	47·3	56·5	53·1	49·5
November ..	166	186	165	146	154	159	162	57·9	58·0	51·5	45·6	48·1	49·5	52·1
December ..	129	137	185	191	165	138	157	40·5	43·0	58·3	59·7	51·1	43·4	49·3

TABLE VI.—No. of Rainy and Overcast Days.

Months.	No. of Days of Rain.							No. of Overcast Days. (Days with less than 1 hour's sunshine.)						
	1888.	1889.	1890.	1891.	1892.	1893.	Mean.	1888.	1889.	1890.	1891.	1892.	1893.	Mean.
January ..	..	20	4	6	11	10	10	..	2	1	6	1	3	3
February ..	..	10	6	4	4	2	5	..	2	2	0	2	4	2
March	..	4	16	4	2	10	7	..	1	7	1	4	1	3
April	..	6	1	3	7	5	4	..	1	3	0	1	2	1
May	..	5	3	2	2	1	3	..	2	5	3	1	2	3
June	..	..	0	0	3	2	1	..	..	4	1	2	0	2
July	..	..	0	1	0	2	1	..	..	9	2	1	10	5
August	..	..	0	1	0	2	1	..	..	..	1	5	1	2
September	..	..	2	1	1	4	2	..	..	4	0	0	2	2
October	3	13	6	5	4	5	6	..	0	2	3	3	2	2
November ..	11	9	12	14	9	9	11	3	2	1	2	2	5	3
December ..	14	17	16	4	9	10	12	4	4	1	0	2	7	3

west and west. For these reasons its meteorological conditions may be considered to approach more closely to those common to this portion of the globe.

As it is impossible within the limits of a short paper to enter into all the details, the shade temperature, the sea temperature, the rainfall, and sunshine are alone considered.

The thermometers for recording the shade temperature were exposed in a Stevenson screen situated in the centre of an extensive flat roof. The temperature of the sea was recorded by an ordinary bath thermometer immersed in the sea at the end of the town mole. It was recorded as near noon as possible, at a depth of 8 feet from the surface and in never less than 20 feet of water, usually much more. The number of observations ranged from ten to fifteen per month. The rain gauge was exposed on the flat roof, which was the highest in the neighbourhood. The sunshine was recorded by means of Jordan's photographic sunshine recorder.

In giving these results I quite recognise that five years' observations (June, July, and September, four years; August three years) are a very short period from which to draw very definite conclusions.

The means of shade temperature show a gradual ascent and a more rapid descent, due principally to the little variation for the months of January, February, and March. In fact, the curve of ascent from April to August closely corresponds to the curve of descent from August to December.

The period of highest temperature occurs in the month of August, the highest mean temperature taking place during the third week. The decrease in the fourth week is due to the fall of the minimum or night temperature; as the maximum or day temperature remains practically stationary during this fourth week.

The 16th and 17th are the hottest days, though the average is rather higher on account of the temperatures recorded in August 1893.

August 1893.	14.	15.	16.	17.	18.	19.	20.
Maximum	80°·5	82°·0	84°·5	85°·5	81°·5	81°·5	80°·5
Minimum	72·5	72·0	75·0	74·0	72·0	73·0	73·5

The temperature of the sea is at its highest level during August and September, but it does not remain at this point for more than three weeks, when it commences to fall. During this period it approximates to the minimum, being the greater part of the time lower than the mean shade temperature. The temperature of this period for one year naturally varies from another, the period of the highest level also shows variations, though if the temperature has not fallen by the end of September the first week of October shows a decline.

TEMPERATURES OF THE SEA (MEANS) AT NOON.

July 31st (4 years)	Sept. 1st (4 years)	Oct. 1st (6 years)	Nov. 1st (6 years)	Dec. 1st (6 years)
72°·9	74°·1	73°·6	71°·7	68°·9

The *Rainfall* of this period is practically *nil*.

The *Sunshine* is remarkably regular with the exception of the second week in August, for which I am not in a position to venture a reason. This fall appears to affect the course of the maximum but not of the minimum temperature.

The *Winds* during these two months prevail continuously from the North to North-east, and their force is 3—4.

During October the temperatures, both of the shade and of the sea, fall considerably; this is particularly so with the shade temperature of the daytime, and this varies according to the time of commencement of the rainy season and the number of days on which rain falls, the amount of sunshine remaining fairly constant, though the sun's rays grow less powerful.

The period of greatest fall in temperature is during the months of November and December, coincident with the period of greatest fall in the sea temperature and with the period of heaviest rainfall; the amount of sunshine

remaining fairly constant. During January the fall in shade temperature continues. This is also a rainy month, though by the latter end of the month the day temperature shows an upward tendency, as the rays of the sun are again increasing in power, but the night shade temperature and the sea temperature still decrease.

The coldest period of the year commences in January, and continues through February to March, though the periods do not correspond at which the day temperature, the night temperature, and the sea temperature are at their lowest points.

The lowest point of the maximum temperature (that is the temperature of the day) occurs about the third week in January, after which it rises, but the minimum or night temperature does not commence to rise till the second week in February, thus following the curve of the sea temperature. The shade temperatures at noon (G. M. T.) and at 9 p.m. follow respectively the maximum and minimum.

From the detail of five years, the lowest temperature is recorded for the day time during the third week of January; after this date the day temperature continues to rise even with occasional fluctuations, but the minimum or night temperature does not show any tendency to rise till the middle of February, which epoch is coincident with both increase of day temperature and sea temperature.

The connection between sea temperature and night temperature is well seen from the following:—

Weeks.	January.					February.				March.			
	1–7.	8–14.	15–21.	22–28.	29–4.	5–11.	12–18.	19–25.	26–4.	5–11.	12–18.	19–25.	26–31.
Temp. 9 p.m. ..	60°5	60°8	61°0	60°4	59°8	59°5	61°1	61°8	61°8	61°0	62°0	61°4	62°7
,, Minimum	57·6	57·5	58·0	57·5	57·7	56·7	57·5	59·0	59·1	58·3	58·6	59·2	59·8
Sea Temperature	66·2	65·8	65·6	65·3	65·2	65·1	65·1	65·0	65·2	65·5	65·5	65·5	65·7

The monthly variation in temperature at this season is slight; the rainy season comes to an end in January, the temperature of the sea is at its lowest point, but the power of the sun is increasing, though the amount registered does not differ to any great degree (February excepted).

The chief rise in the temperatures takes place in the three months April, May, and June.

The mean diurnal variation in temperature is not great; May, June, July, and August show the slightest degree, with a mean of 7°·7 against 9°·5 for the first four months and 9°·3 for the last four. By 9 a.m. the shade temperature has risen 5° or 6° from the minimum, by noon 2° or 3° more, the maximum being reached somewhere about 1 p.m.: by 3 p.m. it has fallen 2°, and by 9 p.m. it is within 2° of the minimum temperature. Although I have no statistics, two maxima and two minima may be found; the first maximum is reached about 8 a.m. and is more marked on a bright sunny morning with little wind. As the breeze freshens between 9 and 10 a.m., the temperature

falls only to rise again towards noon. The first minimum is seen soon after sunset, but between 8 and 9 p.m. the temperature rises very often 3°, but towards midnight a fall commences and the absolute minimum is reached just before sunrise.

There may be a great rise in temperature during the evening, but it is very rare: thus on October 15th, 1893, between 8 p.m. and midnight, there was registered a rise of 9°·7.

October 15th, 1893.	12 Noon.	1 p.m.	2 p.m.	3 p.m.	4 p.m.	5 p.m.	6 p.m.
Shade Temperature	89°·0	87°·5	86°·0	85°·0	85°·0	75°·5	74°·5
Direction—Force of Wind....	SSE 3	..	..	SSE 3	..	WNW 1	..
Barometer	30·00	..	..	29·95	..	..	29·98

October 15th, 1893.	7 p.m.	8 p.m.	9 p.m.	10 p.m.	11 p.m.	12 Midnight.
Shade Temperature.....	74°·5	73°·0	75°·0	78°·0	81°·0	82°·5
Direction—Force of Wind.....	W 2	W 2	Nil	SSE 2	SSE 2	SSE 2
Barometer	..	..	30·00	29·98	..	29·97

This day was very exceptional both in temperature and humidity, and on this day there were two distinct maxima and minima.

Oct. 15th	9 a.m.—9 p.m.	90°·5 (11.30 a.m.)	78°·0 (8 p.m.)
Oct. 15th-16th	9 p.m.—9 a.m.	88°·0 (midnight)	71°·5 (6 a.m.)

The diurnal range varies considerably with the variations in wind and sunshine. With a South wind (that usually dies down at sunset) the range is increased, but the greater part of the increase of range is in the day temperature. With the Northerly winds persisting after sunset the range may be very slight, particularly if the day has been cloudy. I have taken as examples the same period of years, and both periods may be considered exceptional.

Date.	Sunshine. Daily Average.	Shade Temperatures. Max.	Min.	Range.	Mean.
	h. m.				
March 1889–1893. Mean..	6 30	68°·3	58°·9	9°·4	64°·2
Feb. 27–March 5, 1893. „ ..	10 00	75°·1	60°·7	14°·4	67°·9
March 1–6, 1890. „ ..	0 00	60°·9	55°·1	5°·8	58°·2
Extreme Variation ..	..	14°·2	5°·6	..	..

The temperatures of the different localities situated at sea-level vary considerably, the day temperature depending chiefly on the local cloud and consequent obscuration of the sun, the night temperature on the persistence or otherwise of the prevailing winds. Both of these conditions are due mainly to the position, proximity, and height of the mountains.

Locality.	Mountain Ranges.		Effect of Position of Mountains.		Aspect.	Diurnal Range.
	Proximity.	Height.	Sheltered from.	Exposed to.		
Town. Island.		Ft.				About.
Santa Cruz, de la Palma	Close	7000	SW, NW	N, E, S	E	° ° 14—15
Puerto, Oratava, Tenerife	Close	7000	ENE, S, W	WNW, N, NE	N	12—14
Santa Cruz de ,,	Close	4000	SW, NW	N, E, S	SE	12—13
Las Palmas, Grand Canary	20 miles off	6000	SW, W	NW, N, E, SE, S	E	9—10

Vegetation may play some part in the case of the two former places, but the country around the latter two is barren, and more so round Las Palmas than Santa Cruz.

The low range at Las Palmas is mainly due to the continuance of the prevailing winds (Northerly) after sunset. In the other places this Northerly wind tends to die down (locally) and is replaced by a land breeze. In Las Palmas, on those days when there is a great range of temperature, a land breeze from the West is usually noticed.

The sea temperature has been already alluded to, and the detail for Las Palmas is given in Table III. From personal observation it appears to be the same at all the islands; though running along the African coast there is a belt of colder water. This may be very slightly felt at Lanzarote and Fuerteventura. This cold current is inhabited by fish that are not caught off the islands: the catching and salting of these fish form one of the staple industries of the more eastern islands.

The sea temperature around the islands is dependent on causes outside the limits of the archipelago; local presence or absence of sunshine does not cause any difference, a boisterous Northerly wind with a high sea may cause the temperature to fall quicker than usual, or if the temperature is rising to check the rise, but any sudden variation is very rare. As pointed out, the temperature rises the most in May and June, and falls the most in November and December; whether the rainfall through the last three months of the year accounts for this fall it is not easy to say. There is a certain connection between the rainfall and fall of sea temperature, but both are probably due to stormy weather to the northward; this in turn affects the temperature without the sunshine being affected. This may be seen from the table on p. 161.

From Tables IV. and VI. it will be seen that the rainfall for Las Palmas is not great, though it is spread over a large number of days, the average yearly amount being 8·57 ins. Nearly half of this, viz. 4·06 ins., falls on 12 out of the 62 days on which rain is recorded, thus leaving 4·50 ins. to fall on the remaining 50 days. Out of the 8·57 ins. 3·34 ins. falls during the daytime and 5·22 ins. during the night time; naturally rain also falls more frequently during the night time than during the day time, as rain was recorded

Years.	Oct.–Dec. Rainfall.		Temperature of Sea.			October to December.		
						Sunshine.	Shade Temperature.	
	Amount.	No. of Days.	On Oct. 1st.	On Jan. 1st.	Amount of Fall.	Hours.	Noon, G.M.T.	9 p.m.
	Ins.		°	°	°		°	°
1888	2·735	28	74·0	67·8	6·2	495	72·2	67·3
1889	5·348	39	71·5	64·0	7·5	477	69·5	65·6
1890	7·895	34	72·5	65·5	7·0	514	70·3	65·3
1891	3·195	23	74·0	67·0	7·0	504	71·8	66·4
1892	2·800	22	74·0	67·0	7·0	518	71·6	66·4
1893	4·690	24	75·5	66·5	9·0	484	73·1	66·9

as falling on 88 occasions during the daytime with 47½ for the night time, this being the annual average for the five years.

The greater part of the rain falls in October, November, December, and January. For February there is a considerable diminution, with slight increase in March, but the amount further diminishes in April and May, whilst June, July, and August are practically rainless, and September is very similar, the average for this month being almost entirely supplied by one heavy shower. This periodicity of the rainfall, and the slight influence it has on the amount of sunshine, can be well seen from the following figures:—

Period.	No. of Days.	Rainfall.		Sunshine.		No. of Cloudy Days.
		Amount.	No. of Days.	Average Daily Amount.	Percentage.	
		Ins.		h. m.		
October to January.....	123	6·115	38·6	5 25	50·7	9·1
February to May	120	2·118	19·4	6 37	52·2	8·8
June to September	122	·335	4·1	6 22	48·4	11·4

The smallness of the rainfall of Las Palmas is in a great measure due to the absence of the mountainous influence, the major part of it being regulated by the influences of the weather out at sea. The rainfall at sea for this region is of two varieties, one is that associated with the Northerly set of winds. This is the commonest variety, and this rain falls in short sharp showers, very local in character, the weather before and after being fine. These showers can often be seen approaching or passing at some little distance, and are usually heralded by a temporary increase in the force of the wind. The other variety of rainfall is associated with disturbances to the south-west; these are rare, as the eastern islands are somewhat out of the track of these squalls. The rain, however, is of a heavy tropical character, and may be associated with electric phenomena. I have never yet seen a disturbance passing from the north connected with electrical phenomena.

From Table V. the amount of sunshine can readily be ascertained. Depending on the amount of clouds, it may be diminished by general cloudy weather or by the local formation of clouds, though the degree of the latter may often be in proportion to the former. In the case of Las Palmas the sunshine of

the afternoon is often affected by this local cause, as the sky may be fairly clear overhead, yet no sunshine is recorded because the sun has sunk behind masses of clouds that overhang the elevated northern parts of the island to the west of the town.

Excluding February and July, the amount recorded is very regular, being 51·5 per cent. February has 58 per cent. and July 40·5. The number of totally cloudy days—days with one hour's sunshine or less— are not many, for according to Table VI. the average annual number is about 80, the month of July having the largest number. As I have pointed out, the rainfall has little in common with the sunshine. This is dependent on the winds, particularly on the force of the prevailing winds (Northerly), as the greater the force of the Northerly winds there is more liability to both general and local cloudy weather, the "parasol" of clouds hanging more densely over the northern part of the island. With the Easterly and Southerly winds the sky is usually cloudless, but with the South-west winds it is overcast.

In the present paper it is impossible to go into the question of humidity, as it is associated with the winds and this with the barometric pressure. I might briefly point out that the rainless period shows a higher degree of humidity than the rainy periods, and thus corresponds more with the diminution of sunshine. This is seen from the following table:—

Means.	No. of Days.	Rainfall.		Sunshine.		Relative Humidity.			
		Amnt.	Days.	Per-centage.	No. of Cloudy Days.	9 a.m.	Noon.	3 p.m.	9 p.m.
		Ins.		%		%	%	%	%
Oct. to Jan.	123	6·116	38·6	50·7	9·1	68·6	65·6	(66·7)	74·5
Feb. to May	120	2·118	19·4	52·2	8·8	66·6	64·6	(65·8)	74·7
June to Sept. ..	122	·335	4·1	48·4	11·4	69·0	68·2	(70·0)	76·9

The humidity observations for 8 p.m. are not so extensive as those for the other hours, being the means for three years only.

NOTE ADDED MARCH 1894.

I cannot enter into the subject of the winds and the weather connected with them. This would require a separate paper. I might however, indicate by means of the table on the next page the average direction of the wind at noon (G. M. T.) and at 9 p.m., and with this I must bring this long paper to a close.

DIRECTION OF WIND. NUMBER OF TIMES OBSERVED. MEANS FOR 5 YEARS.

Months.	Noon (G. M. T.)						9 p.m.					
	NW., N. & NE.	E.	SE. & S.	SW.	W.	Calm.	NW., N. & NE.	E.	SE. & S.	SW.	W.	Calm.
January....	15·7	2·8	7·5	..	..	3·6	15·0	·6	2·3	..	6·6	6·4
February ..	13·5	4·5	8·2	..	..	1·7	15·4	·6	·6	..	4·6	7·0
March	20·2	5·2	5·2	..	..	·2	21·8	·4	·1	..	3·8	4·6
April	26·4	1·0	2·0	..	..	·5	25·8	..	..	..	1·8	3·0
May	27·5	2·6	·6	..	..	..	27·1	..	..	..	·4	3·5
June	29·0	·3	..	..	..	·6	29·3	..	..	..	..	·6
July	30·0	·6	..	..	..	..	28·3	..	..	..	·3	2·3
August	30·3	·3	..	..	..	·3	29·0	..	..	..	..	2·0
September..	26·6	·8	·3	..	..	2·0	22·6	·3	·2	..	4·0	2·6
October	23·5	2·6	3·4	..	..	1·4	19·0	·8	·6	..	4·4	5·2
November .	21·0	3·2	2·6	..	..	3·2	18·4	·6	·2	..	6·2	4·2
December ..	18·0	4·6	4·4	..	..	4·4	17·8	1·0	..	..	6·4	5·4

DISCUSSION.

Mr. A. BREWIN remarked that the paper would have been improved and rendered more interesting if further information had been given concerning the winds at Grand Canary, the references in the paper to this important factor in climate being very few, and in one place where it was stated that the wind for two months was continuously North to North-east, it was very doubtful which two months were referred to.

Mr. C. HARDING said that the Canary Islands being situated to the east and somewhat south of the area of high pressure in the Atlantic, the prevailing direction of the wind would be North and North-east. In the Tables accompanying the paper the small range of temperature was a very noticeable feature; this was particularly the case in 1889, and in January of that year the range between the absolute maximum, 67°·5, and the mean maximum, 65°·2, was only 2°·3. The minimum temperatures for the same month also exhibited a similarly small variation, the absolute being 55°·0, and the mean 57°·4. Possibly these figures were correct, although a person accustomed to examine and analyse meteorological data might reasonably suspect their accuracy, and be inclined to think that for that month, at any rate, the observations were probably incomplete. No doubt the information given in this paper was of considerable value, particularly from a medical point of view, as the Canary Islands were now coming into prominence as health resorts. From a meteorological standpoint objection must be taken to the manner in which the averages had been struck, some monthly means being based on five years' observations, some on four years', and one on three years'. Although a three-year average was a very poor one, it would be better to have all the means for a uniform period rather than for a varying number of years.

THE PRESIDENT (Mr. R. Inwards) said that no doubt the Canary Islands were coming to the front as health resorts for invalids, and any information concerning their climate was both interesting and valuable, but a friend who had resided at Las Palmas for a time told him that there was a great want of sanitation, and that with efficient drainage the town would be a perfect place of residence.

Mr. W. MARRIOTT said that Mrs. Stone, in her book *Tenerife and its Six Satellites*, gave some account of the climate of the Canary Islands, which agreed with the results of Dr. Taylor's observations. The French Bureau Central Météorologique also had a station at Las Palmas, the results of the observations from which were published in the *Annales*.

Comparative Observations with two sets of Instruments at Ilfracombe, North Devon, during 1893.

By WILLIAM MARRIOTT, F.R.Met.Soc.

[Read February 21st, 1894.]

At the Meeting of the Society on June 15th, 1892, Mr. Bayard read a paper on "English Climatology, 1881-1890," in which he gave the results of the climatological observations for the 10 years at all the Society's stations. In the discussion which ensued some exception was taken to the Ilfracombe observations, as the thermometers were not mounted in a Stevenson screen; and it was thought that the high winter temperatures were not natural, but were really due the method of exposure.

The following account of the station was given in my Inspection Report[1] for 1880:—

"The instruments are exposed in a large screen, like a summer-house, the rain-gauge being on the top and having a pipe with a tap below. The stand is about 6 feet square, has large louvres half way down, then lattice work, is painted green, and has a slated pyramidal roof. It is placed over the shingle promenade of the Ilfracombe Hotel, and is 8 or 10 feet from the embankment, which rises about 16 feet. The exposure is quite open to the sea from the west to north. Capstone rock is about 200 yards distant on the north-north-east. On the borders and outskirts of the town, hills rise to the height of 500 to 800 feet. The whole of the soil is shale."

Although this screen was not of the regular pattern, I was of opinion that the temperature observations taken in it would be fairly comparable with those in a Stevenson screen.

On each of my visits to Ilfracombe I made inquiries as to the possibility of getting another station started in the town. On my last visit, in August 1892, I called on the Manager of the Ilfracombe Hotel, and pointed out to him the desirability of a Stevenson screen and a Snowdon rain gauge being obtained and placed over grass, so that no question could be raised as to quality of the observations, and that they might be strictly comparable with those from the other stations of the Society. I selected a site for the thermometer screen and rain gauge on the lawn to the east of the Hotel, and to the south of the old screen. The Directors subsequently carried out this recommendation; and the new instruments were put up at the beginning of October 1892.

The Stevenson screen is about 60 feet south of the old screen, and 96 feet from the wall of the Hotel; the rain gauge is about 90 feet from the old screen, and 90 feet from the Hotel.

[1] *Quarterly Journal*, Vol. VII. p. 109.

As the observations from these two sets of instruments have now been carried on simultaneously by Mr. M. W. Tattam, the observer, for more than a year, I think the Fellows will be interested in having the results for the twelve months, January to December 1893. These are given in the accompanying Table.

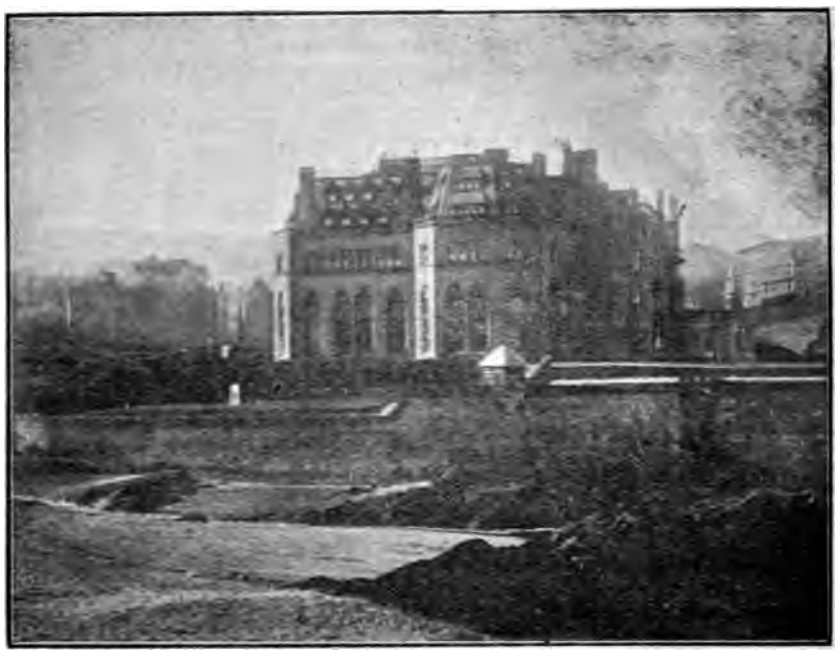
RESULTS OF COMPARATIVE OBSERVATIONS WITH TWO SETS OF INSTRUMENTS AT ILFRACOMBE DURING 1893.

1893.	Temperature—Means.														
	9 a.m.			Minimum.			Maximum.			Range.			Mean.		
	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°	°
January	41·4	40·8	—0·6	37·8	38·0	+0·2	43·8	43·9	+0·1	6·0	5·9	—0·1	40·8	41·0	+0·2
February	45·1	44·4	—0·7	40·9	41·1	+0·2	48·4	48·5	+0·1	7·5	7·4	—0·1	44·7	44·8	+0·1
March ..	48·7	48·3	—0·4	42·8	43·1	+0·3	54·0	54·0	0·0	11·2	10·9	—0·3	48·4	48·5	+0·1
April	53·0	52·7	—0·3	46·6	47·0	+0·4	60·1	60·5	+0·4	13·5	13·5	0·0	53·3	53·8	+0·5
May	56·8	56·7	—0·1	51·6	52·0	+0·4	61·7	62·1	+0·4	10·1	10·1	0·0	56·7	57·0	+0·3
June	61·3	61·0	—0·3	55·2	55·6	+0·4	65·7	66·1	+0·4	10·5	10·5	0·0	60·4	60·9	+0·5
July	62·8	62·6	—0·2	58·2	58·5	+0·3	66·2	66·4	+0·2	8·0	7·9	—0·1	62·2	62·4	+0·2
August ..	65·0	64·6	—0·4	59·8	60·1	+0·3	69·1	69·3	+0·2	9·3	9·2	—0·1	64·5	64·7	+0·2
September	59·9	59·5	—0·4	54·8	55·4	+0·6	62·6	62·9	+0·3	7·8	7·5	—0·3	58·7	59·2	+0·5
October ..	55·3	55·0	—0·3	50·5	50·9	+0·4	58·3	58·4	+0·1	7·8	7·5	—0·3	54·4	54·6	+0·2
November	46·7	46·5	—0·2	42·7	43·1	+0·4	49·7	49·9	+0·2	7·0	6·8	—0·2	46·2	46·5	+0·3
December	46·7	46·3	—0·4	41·6	42·0	+0·4	49·6	49·9	+0·3	8·0	7·9	—0·1	45·6	46·0	+0·4
Year ..	53·6	53·2	—0·4	48·5	48·9	+0·4	57·4	57·7	+0·3	8·9	8·8	—0·1	53·0	53·3	+0·3

1893.	Temperature—Extremes.									Relative Humidity.			Rain.		
	Minimum.			Maximum.			Range.								
	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.	Stevenson.	Old Screen.	Difference.	Snowdon, 1 foot.	Old Gauge, 9 feet.	Difference per cent.
	°	°	°	°	°	°	°	°	°	%	%	%	Ins.	Ins.	%
January	28·4	28·3	—0·1	53·5	53·6	+0·1	25·1	25·3	+0·2	85	87	+2	2·57	1·99	—23
February ..	32·5	33·3	+0·8	55·9	56·0	+0·1	23·4	22·7	—0·7	85	87	+2	5·62	4·44	—21
March	37·5	35·7	—1·8	63·8	64·0	+0·2	26·3	28·3	+2·0	85	85	0	·52	·41	—21
April	35·7	36·1	+0·4	78·9	78·0	—0·9	43·2	41·9	—1·3	78	81	+3	·22	·17	—23
May	44·9	45·3	+0·4	74·7	75·6	+0·9	29·8	30·3	+0·5	85	84	—1	2·75	2·51	— 9
June	49·9	50·5	+0·6	79·7	80·0	+0·3	29·8	29·5	—0·3	85	86	+1	1·10	·93	—15
July	52·4	52·8	+0·4	78·9	79·0	+0·1	26·5	26·2	—0·3	86	86	0	5·15	4·40	—15
August.....	52·9	54·3	+1·4	82·9	83·2	+0·3	30·0	28·9	—1·1	85	85	0	2·13	1·75	—18
September ..	46·9	47·9	+1·0	72·9	73·2	+0·3	26·0	25·3	—0·7	80	82	+2	3·01	2·37	—21
October	36·9	38·3	+1·4	65·3	65·6	+0·3	28·4	27·3	—1·1	83	82	—1	5·14	4·02	—22
November ..	35·4	36·3	+0·9	57·8	58·0	+0·2	22·4	21·7	—0·7	85	85	0	2·63	2·00	—24
December ..	28·9	29·9	+1·0	55·2	55·2	0·0	26·3	25·3	—1·0	86	85	—1	6·27	5·09	—19
Year	..	..	+0·5	..	..	+0·2	..	..	—0·3	84	85	+1	37·11	30·08	—19

At 9 a.m. the temperature in the Stevenson screen is on the average 0°·4 higher than in the old screen. With regard to the mean minimum and maximum, the old screen records a higher temperature than the Stevenson

screen, the excess for the minimum being 0°·4, and for the maximum 0°·3. The mean temperature, as deduced from the observations made in the old screen, is 0°·3 higher than that from those made in the Stevenson screen. The extremes show practically the same result; the mean of the absolute minima being 0°·5, and the mean of the absolute maxima being 0°·2, higher in the old screen than in the Stevenson screen.



The relative humidity does not show much variation, the mean for the year being 1 per cent. greater in the old screen than in the Stevenson screen.

The difference in the amounts of rain collected by the two gauges is somewhat considerable, as was to be expected, the old gauge being 9 feet above the ground and placed on the top of the thermometer screen, while the new gauge is of the Snowdon pattern, the rim being 1 foot above the ground. The total rainfall collected by the Snowdon gauge during the year was 37·11 ins., while the old gauge collected only 30·08 ins., the difference being 19 per cent.

The results from the new set of instruments have been printed in the *Meteorological Record* since January 1893 in place of those from the old instruments.

DISCUSSION.

Mr. R. J. LECKY sent the following note, which was read by the Secretary:—"Were I with you on Wednesday I should probably make a remark or two on Stevenson's clever and valuable screen, now, I presume, in almost universal use, so that if there be any fault in its construction occasioning an error it becomes a "constant" in any comparisons of temperature with other observations.

What I fear in these screens is a want of proper ventilation, and that in extremely hot sultry weather, especially where they are exposed to the full sun, they become a species of oven and give too high a temperature (I do not so much fear a *vice versa* effect in winter) *e.g.* my Six thermometer, in a fairly sheltered open air position, where it agrees well with others, gave 87° as the highest last summer, while 93° was reported from, I presume, a Stevenson screen. It would be interesting if some meteorologists would make a series of observations with a well defended open air thermometer and that in a screen; it would of course require a fairly long series, so as to eliminate extra disturbances. As to the ventilation I allude to, I have always thought that the louvring was overdone in being doubled and too small a distance between the laths; as also that the louvring ought to be vertical instead of horizontal as at present, in fact on the principle of "Day's" wind guard for chimney tops (made as in his original patent of 40 or 50 years ago, not as scamped by present makers), which would not hamper the free ventilation as the present double confined louvring does.

Mr. C. LAWRENCE said that, being a frequent visitor to Ilfracombe, he had, in November last, made an inspection of the screens in which the thermometers are placed there, and had also interviewed Mr. M. W. Tattam, who takes the records with the approval of the Society, and who was evidently perfectly well qualified to make observations, carrying out the work in a conscientious manner. The Society had done a good thing in establishing a Stevenson screen and making comparative observations between the temperatures in that screen and those in the old form of shelter, for the result clearly showed that the temperature of Ilfracombe as registered in the old screen was practically correct, and that the fact of its having the highest mean temperature in the United Kingdom was well established.

Mr. E. MAWLEY, referring to Mr. Lecky's letter, said that no better refutation of the idea that a Stevenson screen was likely to become heated up "like an oven," owing to its want of sufficient ventilation, could be given than the photograph of the Ilfracombe screen, which showed that whatever the other defects of that screen might be it was at all events freely ventilated on all sides; and yet on turning to the Table of comparative observations it would be seen that on the hottest days of last year the Stevenson screen comes out as rather the cooler of the two. He had made various experiments with the Stevenson screen in order to determine its suitability for the exposure of thermometers, having compared the records of one of these screens, sheltered at the top and sides with canvas and placed in full sunshine with an ordinarily exposed screen also in sunshine, and also a screen placed in the shade of a tree with one fully exposed to the sun's rays, the results of these various tests showing that the differences between ordinary exposure and shaded exposure were but slight. He regarded the Stevenson screen, all things considered, as the best form of exposure for thermometers; but he was glad that the records of the old screen at Ilfracombe were found to approximate so closely to those of the Stevenson screen, as if it had been otherwise a long series of observations would have been spoiled.

Mr. F. C. BAYARD said that in the discussion on his paper on "English Climatology, 1881-90," read at the meeting of the Society on June 15th, 1892, Mr. Symons had expressed considerable doubt concerning the accuracy of the temperatures at Ilfracombe, believing that the peculiar construction of the screen caused too high a temperature to be recorded. It was very satisfactory to find that such was not the case, and that the exceptional warmth of Ilfracombe was entirely due to its sheltered situation, so that it was one of the warmest places in the British Isles, excepting the Channel Islands.

Mr. C. HARDING said that the large form of screen at Ilfracombe appeared to bear some resemblance to the thermometer shelter used in India, and it was very gratifying, although somewhat surprising, that the results from the Stevenson screen agreed so well with those from the old screen. Much variation between the mean values in the different screens was hardly to be expected, but the extreme temperatures also exhibited very small differences. He had on some occasions noticed as much as a difference of 1° between two similar thermometers in a Stevenson screen, and in the morning had seen the maximum thermometer indicating a lower temperature than the dry bulb; the difference being apparently due to the sun shining on the side of the screen to which the dry bulb was in closest proximity.

Mr. R. H. Scott drew attention to the form of thermometer shelter used at the Ordnance Survey Office, Dublin, from 1842 to 1879, when a Stevenson screen was supplied by the Meteorological Office. It was described and illustrated in an Ordnance Survey publication entitled *Meteorological Observations taken during the years 1829 to 1852 at the Ordnance Survey Office, Phœnix Park, Dublin.* The description was as follows:—"The Observatory.....is an octagonal wooden structure, with a dome shaped roof: the length of the exterior side is 6 feet, and the height above the ground to the springing of the ellipsoidal dome 7 feet 4 inches. Each side consists of an external and internal frame, of fixed louvred work, having a space of 6 inches between the frames. Alternate sides are made to open like folding doors, but it was not usual to open any one of the sides except occasionally for the purpose of admitting more light at the time of reading."

The President (Mr. R. Inwards) said that it was satisfactory to find that the temperature observations agreed so closely despite the difference in the construction and size of the two screens, 0°·5 being the extreme limit of error. The variation in the rainfall was, however, considerable, and he hoped that some satisfactory explanation would be given of the divergence of 19 % which had been found to exist between the two gauges, as the comparatively slight difference in their situation did not appear to be sufficient to account for so large an error as 19 %. Regarding Mr. Lecky's remarks and suggestions, it did not appear that vertical louvring possessed any advantages over the form of louvres as now constructed. Prof. Tyndall's idea of the manner in which a thermometer should be exposed was to suspend a spirit thermometer in the open air on a cord or string stretched between two posts fixed in the ground.

Mr. W. Marriott said that Dr. Buchan had informed him that a somewhat similar screen had been in use for many years at Braemar. A short time ago a Stevenson screen was set up beside it, and comparative observations made in the two screens, when results were obtained which were similar to those at Ilfracombe.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

January 17th, 1894.

Ordinary Meeting.

C. Theodore Williams, M.A., M.D., President, in the Chair.

John Alfred Fox, L.R.C.P., M.R.C.S., Tregea House, Penzance;
Frederic Merrifield, 24 Vernon Terrace, Brighton; and
Thomas James Scott, Edlestone House, Prestatyn, Rhyl,
were balloted for and duly elected Fellows of the Society.

Robert Lewis John Ellery, F.R.S., Government Observatory, Melbourne; and
Dr. Maurits Snellen, Royal Meteorological Institute of the Netherlands, Utrecht, were balloted for and duly elected Honorary Members of the Society.

The Secretary stated that the Council had requested the following letter from the President to be read to the Society:—

"2 Upper Brook Street, W.
"January 7th, 1894.

"Gentlemen,

"As I shall shortly retire from the Presidency of the Royal Meteorological Society, the tenure of which office for two years I shall always regard as

a high honour conferred on me by a learned and scientific Society, I wish to leave behind some memorial of my pleasant term of office, and after considering the matter carefully, and consulting with some of our colleagues, I have decided to present the sum of £100 to form the nucleus of a Research Fund, to defray the expenses of such experiments and observations in meteorology as the Council may from time to time think fit to investigate.

"I would instance, as the kind of work contemplated, the Wind Force experiments, and the observations taken on the Boston Church Tower.

"In the event of no grants being made for a while from the Fund, the money is to be invested and the interest allowed to accumulate to augment the sum available for future grants.

"Hoping that the institution of such a fund will forward the progress of the Society, of which there is no more ardent admirer than myself, thanking you warmly for the support and indulgence you have extended to me during my term of office, and with all good wishes for you collectively and personally,

"I remain,
"Yours faithfully,
"C. THEODORE WILLIAMS."

"The Council of the Royal Meteorological Society."

MR. R. H. CURTIS exhibited and described some lantern slides showing the wind records obtained from the Dines' Anemometer at Westminster, and from the Bridled Anemometer at Holyhead, during the November gale. (p. 43.)

January 17th, 1894.

Annual General Meeting.

C. THEODORE WILLIAMS, M.A., M.D., President, in the Chair.

MR. F. B. EDMONDS and MR. H. HARRIES were appointed Scrutineers of the Ballot for Officers and Council.

MR. F. C. BAYARD read the Report of Council and the Balance Sheet for the past year (p. 92).

It was proposed by the PRESIDENT, seconded by Mr. F. C. BAYARD, and resolved:—"That the Report of the Council be received and adopted, and printed in the *Quarterly Journal*."

It was proposed by Mr. A. BREWIN, seconded by Mr. W. M. BEAUFORT, and resolved:—"That the thanks of the Society be given to the Officers and other Members of Council for their services during the past year."

It was proposed by Mr. F. J. BRODIE, seconded by Capt. W. F. CABORNE, and resolved:—"That the thanks of the Society be given to the Standing Committees and to the Auditors, and that the Committees be requested to continue their duties till the next Council Meeting."

It was proposed by the Hon. F. A. R. RUSSELL, seconded by Dr. R. BARNES, and resolved:—"That the best thanks of the Royal Meteorological Society be communicated to the President and Council of the Institution of Civil Engineers for having granted the Society free permission to hold its Meetings in the rooms of the Institution."

The PRESIDENT then delivered an Address on "The Climate of Southern California" (p. 81).

It was proposed by Mr. BALDWIN LATHAM, seconded by Sir RICHARD QUAIN, and resolved:—That the thanks of the Society be given to Dr. C. THEODORE WILLIAMS for his services as President during the past year and for his generous gifts, and also for his Address, and that he be requested to allow that to be printed in the *Quarterly Journal*."

The Scrutineers declared the following gentlemen to be Officers and Council for the ensuing year :—

President.

RICHARD INWARDS, F.R.A.S.

Vice-Presidents.

ROBERT BARNES, M.D., F.R.C.P.
HON. FRANCIS ALBERT ROLLO RUSSELL, M.A.
STEPHEN WILLIAM SILVER, F.R.G.S.
CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

Treasurer.

HENRY PERIGAL, F.R.A.S., F.R.M.S.

Secretaries.

FRANCIS CAMPBELL BAYARD, LL.M.
GEORGE JAMES SYMONS, F.R.S.

Foreign Secretary.

ROBERT HENRY SCOTT, M.A., F.R.S.

Council.

ROBERT WILLIAM PEREGRINE BIRCH, M.Inst.C.E., F.G.S.
GEORGE CHATTERTON, M.A., M.Inst.C.E.
WILLIAM HENRY DINES, B.A.
WILLIAM ELLIS, F.R.S., F.R.A.S.
CHARLES HARDING.
BALDWIN LATHAM, M.Inst.C.E., F.G.S.
ADMIRAL JOHN PEARSE MACLEAR, R.N., F.R.G.S.
WILLIAM MARCET, M.D., F.R.S., F.C.S.
EDWARD MAWLEY, F.R.H.S.
HENRY SOUTHALL, F.R.H.S.
WILLIAM BLOMEFIELD TRIPP, M.Inst.C.E.
CAPT. DAVID WILSON-BARKER, F.R.G.S.

Dr. C. T. WILLIAMS having left the Chair, it was taken by Mr. R. INWARDS, the newly elected President, who thanked the Fellows for the honour they had conferred upon him in electing him to that office.

February 21st, 1894.

Ordinary Meeting.

RICHARD INWARDS, F.R.A.S., President, in the Chair.

RICHARD MANLIFFE BARRINGTON, M.A., LL.B., F.L.S., Fassaroe, Bray, Co. Wicklow ;
C. G. LUMLEY CATOR, 7 Southwick Place, Gloucester Square, W. ; and
HENRY OWEN, F.R.G.S., 26 Albion Street, Hyde Park, W.,
were balloted for and duly elected Fellows of the Society.

The following Papers were read :—

"REPORT ON THE PHENOLOGICAL OBSERVATIONS FOR 1893." By EDWARD MAWLEY, F.R.Met.Soc. (p. 125.)

"TEMPERATURE, RAINFALL, AND SUNSHINE AT LAS PALMAS, GRAND CANARY." By J. CLEASBY TAYLOR, M.D. (p. 154.)

"COMPARATIVE OBSERVATIONS WITH TWO SETS OF INSTRUMENTS AT ILFRACOMBE DURING 1893." By WILLIAM MARRIOTT, F.R.Met.Soc. (p. 164.)

CORRESPONDENCE AND NOTES.

The late Arthur Hill Hassall, M.D.—Dr. Hassall's work in Natural History, Hygiene, on Food, in Physiology and Medicine was so striking that his contributions to Meteorology have hardly received the recognition they deserve. His work in this direction was not merely devoted to barren observation; but he applied it to the practical objects of the preservation of health and the cure of disease. It would be difficult to find in the history of Medicine a more valuable example of the application of meteorological science than that supplied by the National Hospital for Consumption at Ventnor, founded by him. The principle of isolation of the patients, thus securing to each air free from mutual contamination, and so avoiding "hospital air," was here first put into practice. The next point was that each patient's bed-room should face south. All the other arrangements were made to harmonise with this leading idea. Another illustration of Dr. Hassall's attention to meteorology—that is, of making air the vehicle of healing agents—was his advocacy of the treatment of consumption by inhalation. Space will not admit of dwelling further upon this topic. But we cannot close this brief notice without recording one—the last proof of the keen devotion to the study of nature which animated him throughout.

He had kept up a systematic observation of the Meteorological phenomena at San Remo for the last twelve years. This fact, and the knowledge that he was ever ready to enter upon new fields of investigation, induced me to seek his aid in carrying out the proposition I had started in the Royal Meteorological Society, to observe the changes in the constitution and properties of the air under different conditions. I wrote to him last February asking him to note the proportion of salt in the rain-water falling near the sea; that we might have a standard of comparison with rain coming from other seas besides the Mediterranean and further inland. He immediately set to work. In a letter dated February 21st, he says: "No rain fell for some days after your letter. I have now, however, obtained two separate samples, and have determined the chloride of ammonium in each case. The amount in each case is nearly identical, namely, 0·040 per litre, equal in round numbers to about a grain. The smallness of the quantity is perhaps to be explained by the fact that there was no wind from the sea at the time." On March 27th, he writes again, "In my own view of my case I think that there is little hope of contemporary recovery. With regard to salt in the air over the sea, it is astonishing, considering the winds, how little evidence there is of the presence of salt. One never feels it on one's lips; it never accumulates on the window panes; and it is only now and again, owing to the absence of sea-weed, that you ever even get a sniff of the sea. The only evidence of saltness is that steel articles after a good deal of exposure become somewhat rusty."

So that to the last he sought to unravel the arcana of Nature. On April 9th he died. No man had a better claim to the epitaph, "*Non omnis moriar.*"—ROBERT BARNES.

Waterspout in Somerset, April 26th, 1894.—A severe thunderstorm passed over the neighbourhood of Chew Stoke about 8 a.m. on Thursday, April 26th. In the height of the storm a waterspout was seen forming on Black Down, a high point on the Mendips, just above the village of Blagdon. The storm passed over Breach Hill in a north-easterly direction, accompanied by a cyclonic disturbance, which, however, only embraced a narrow path. On reaching Chew Stoke the tiles on a house were dislodged, causing great alarm to the inmates. At Chew Magna, which was in the path of the storm, the roofs of some carpenters' workshops were much damaged.

Atmospheric Electricity.—Observations have lately been made from the Eiffel Tower to ascertain the voltage variations at different heights and upon different days. The diurnal variations are the more consistent the greater the height; there is a minimum voltage in the morning and a maximum in the evening. The morning readings agree, as to time of minimum, whether taken upon the top of the tower or on the level; the evening maximum occurs one hour sooner upon the tower than upon the level. The mean potential was 3,000 volts, frequently rising above 10,000.—*Electrical Review.*

Lightning and Trees.—M. Dimitrie has found that different kinds of wood have very different conductivities for the sparks of a Holtz machine. Oak was easily pierced, but beech was highly resisting. The quantity of water present was not so important as the amount of oil. Woods containing starch, and but little oil, like oak and poplar, have much less resistance to sparking than those containing oil, like the beech. Pine, which contains oil in winter much more than in summer, is comparable with oak in resistance to sparks. When the oils are extracted by ether, these woods are as easily pierced as the starch varieties. Those containing starch are less easily pierced when living than when dead ; the bark and foliage in all the trees are poor conductors. The conclusions accord with the observations that in a certain case 159 oaks were struck by lightning, as against 21 beeches and 59 pines. The danger of being struck, taking beech as the standard, is 5 for Norway pine, 33 for pine, and 48 for oak.—*Electrical Review.*

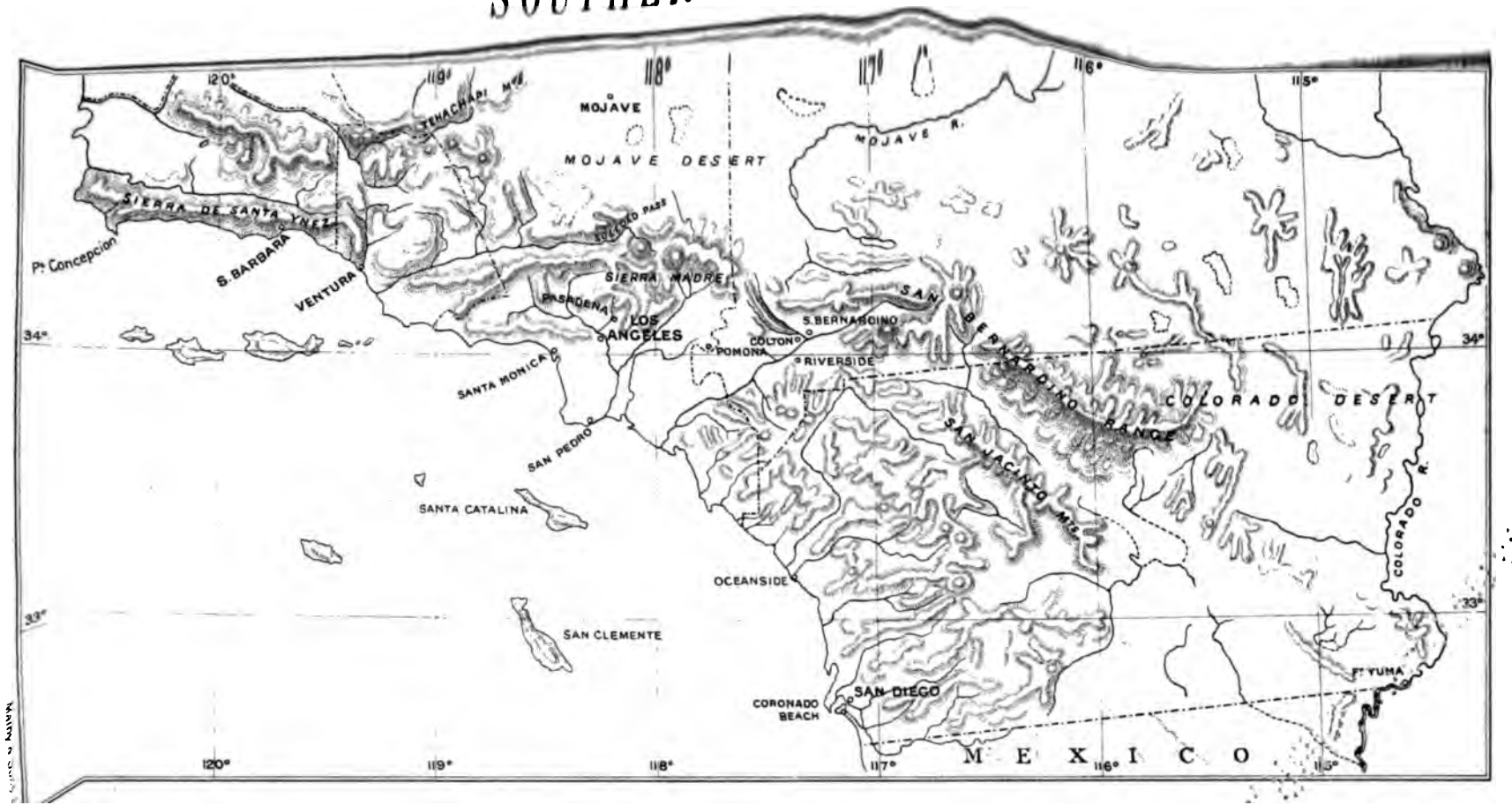
Tornado at Novska, May 31st, 1892.—Mons. A. Mohorovicic has communicated an interesting paper on this tornado to the South Sclavish Academy of Science and Art. Novska is a town on the Save about one third of the way between Agram and Belgrade, and just on the southern edge of the hills lying between the Save and the Drave. On the afternoon of May 31st, the four o'clock train going eastwards was caught by the whirlwind when it had got about 150 yards from the station. The last four carriages were thrown off in a south-west direction, the front of the train in a north-east direction. The middle carriages were uninjured. One carriage, weighing 13 tons with three passengers, was apparently carried over the hedge and the telegraph wires for a distance of 30 yards. The hedge and wires were uninjured. The passengers' accounts of their experiences are contradictory, and small wonder! The guard was thrown out at an early stage of the performance. No one was killed, but a great deal of damage to buildings was reported. One girl, looking after a flock of geese, was caught up by the wind and came to herself after her flight with only a scratch on the hand. A bystander saw her in the air, and her long hair-pins were found 300 yards from her final stopping place. A map giving the directions of the different groups of fallen trees in the adjacent forests shows that the circulation was cyclonic. The greatest force was apparently exerted on the tail of the train.

Large Hailstones at Sea.—The following is an extract from the Meteorological Log No. 9,156, kept on board the S.S. *Anglian*, by Captain F. J. Mosley :—

"October 8th, 1893. Position at noon, lat. 47°3′ N. long. 6°22′ W., 8.30 a.m. Heavy thunderstorm accompanied by hail of the size of walnuts. Wind fell light, continued veering and backing between West and South-south-east, with hard rain squalls at short intervals for two hours, then steadied at South-south-west. The hailstones in this shower were of phenomenal size, many being an inch in diameter. Two actually measured were 1¼ inches in diameter."

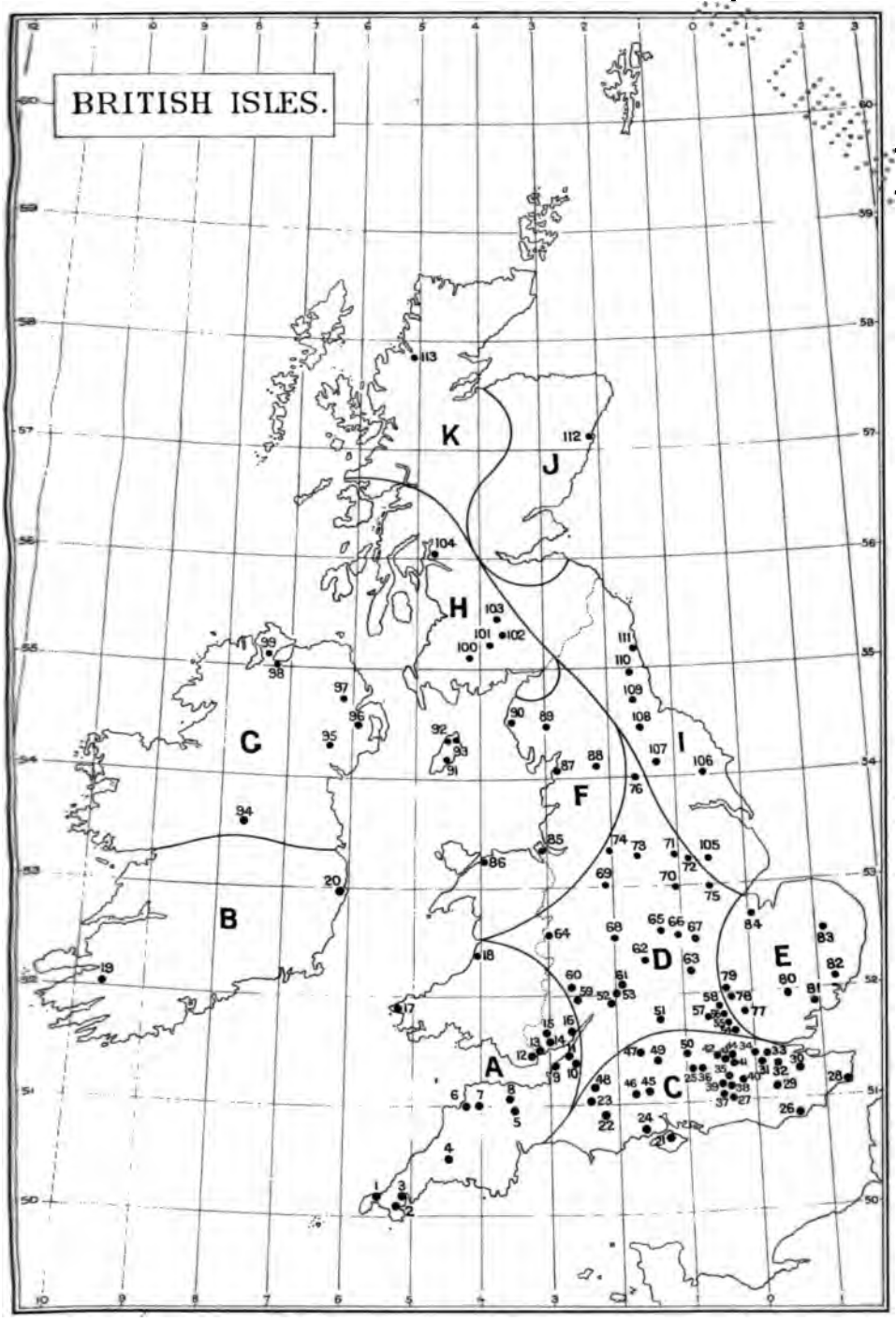
Monthly Weather Report for Russia.—With January 1893, the Russian Meteorological Office commenced the issue of a Monthly Weather Report for agricultural purposes, somewhat corresponding to our own *Weekly Weather Report.* The Russian paper does not deal with accumulated temperature at all, and treats of decades, not of calendar weeks. It gives, however, barometrical data which are entirely absent from the British report. The stations for which data are furnished are the Telegraphic Reporting Stations of the Russian and Finnish system, and numbered 73 in 1893. The barometer is entered without any comparison with standard means. The temperature is given for the decades and the month with difference from the mean in each case. Absolute max. and min. for the month are given for such stations as observe these phenomena or either of them. The other information contained in the table on the first page relates to relative humidity, amount of cloud, and wind frequency (8 points). Rain, with difference from averages for decades and months, is given for 312 stations, and also the number of days of snow covering, and the Report is accompanied by a map.

SOUTHERN CALIFORNIA.

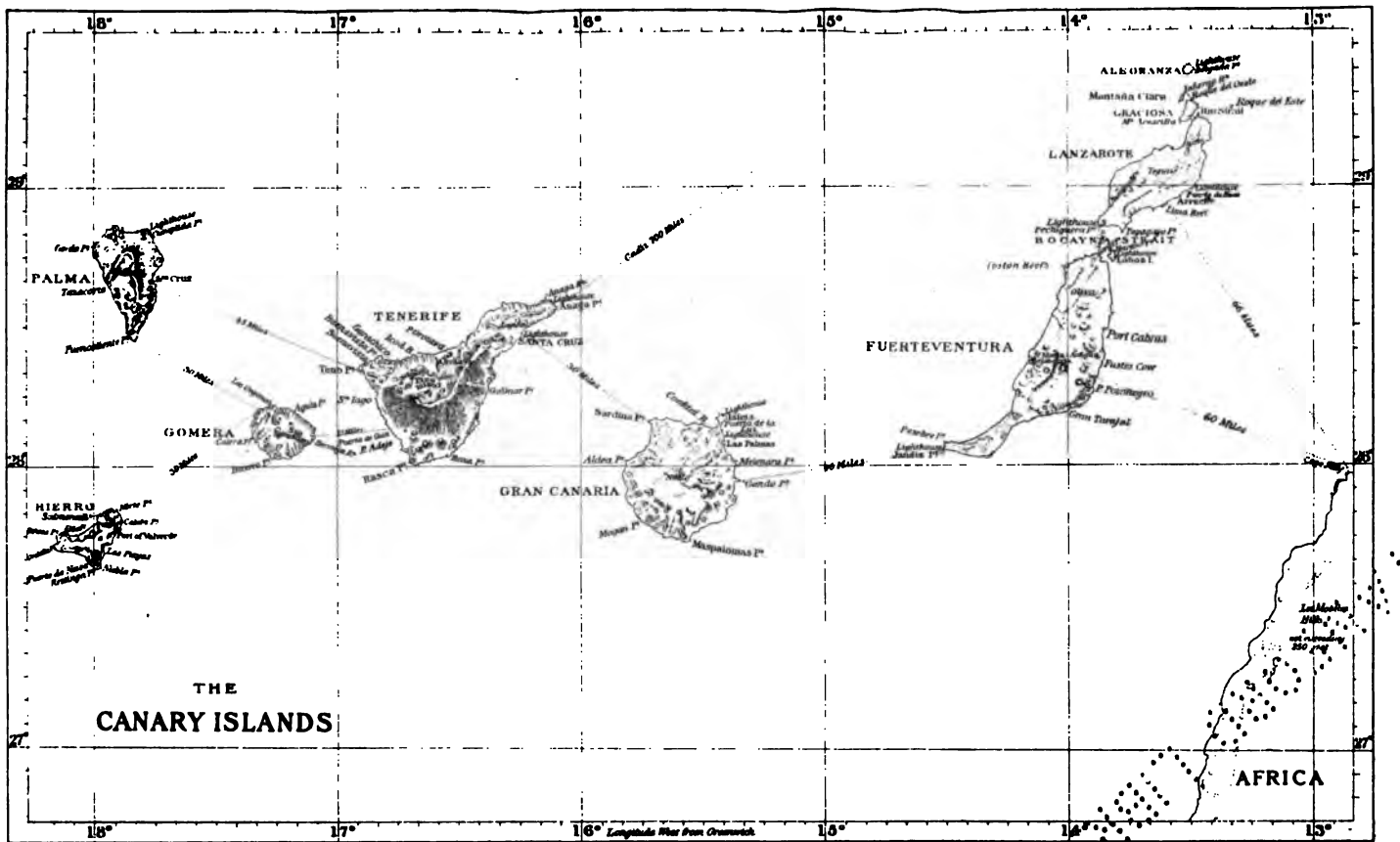


Quart. Journ. Roy. Met. Soc. Vol. XX. Pl. 1.

MAP SHOWING POSITION OF THE PHENOLOGICAL STATIONS, 1893.



For the Names of the Stations see List of Observers, Page 130.


18°
17°
16°
15°
14°
13°
29°
28°
27°
ALEGRANZA
Montaña Clara
GRACIOSA
LANZAROTE
Teguise
BOCAYNA STRAIT
Port Cabras
Fuentis Cove
FUERTEVENTURA
PALMA
TENERIFE
SANTA CRUZ
GOMERA
HIERRO
GRAN CANARIA
Canary 300 Miles
60 Miles
90 Miles
AFRICA
THE
CANARY ISLANDS
Longitude West from Greenwich
Quart Journ Roy Met Soc Vol XLI Pl 3
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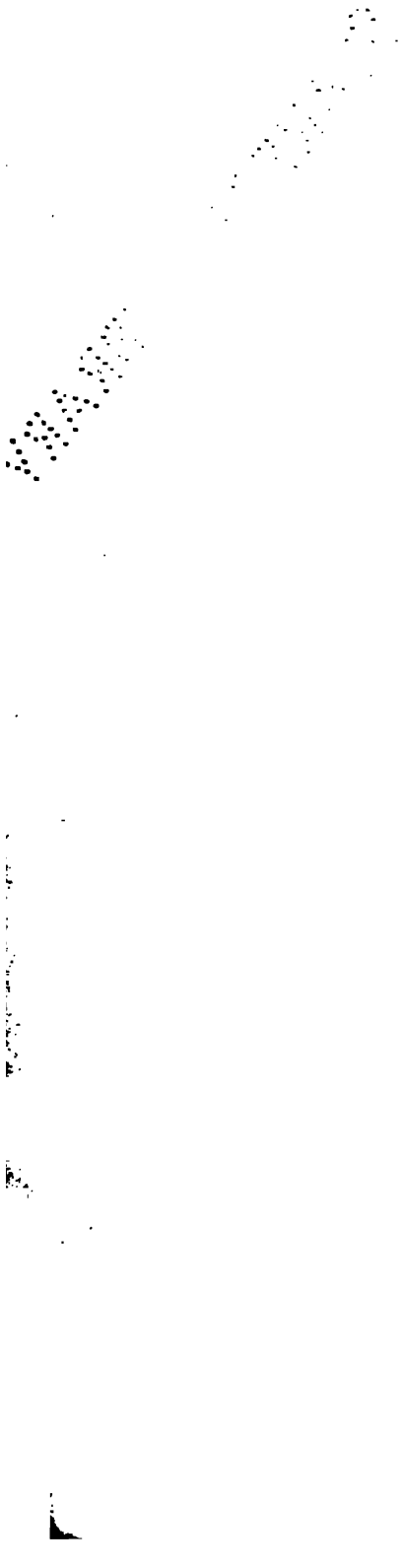

WALDO LIBRARY

LUKE HOWARD, F.R.S.

Born 1772; died 1864.

(*From a Drawing by Bedford about 1843.*)

QUARTERLY JOURNAL

OF THE

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ON THE RELATION BETWEEN THE MEAN QUARTERLY TEMPERATURE AND THE DEATH RATE.

By W. H. DINES, B.A., F.R.Met.Soc.

[Received February 21st.—Read March 21st, 1894.]

Having been struck by the continuously high weekly death rate during the last, remarkably hot, summer, I was led, as a matter of curiosity, to tabulate the returns for preceding years, to see whether the occurrence was merely a coincidence or a general rule.

The *Quarterly Returns* of the Registrar-General for the whole of England, published since 1862, have been taken, and the number of deaths each quarter expressed as a departure per thousand, *plus* or *minus*, from that particular quarter's average; the value so obtained being placed side by side with the corresponding departure of the temperature from its mean value.

It is well known that down to about 1888 a steady decrease of the death rate occurred, a decrease which has now unfortunately ceased. It is obvious that it would not be fair to compare the rate at either end of the period with

the mean for the whole, hence the 32 years have been divided into thre nearly equal parts and the rate compared with the average of the part i which it occurred.

The Registrar General's returns relate to the civil quarter (January-Mar &c.), but the temperature has been taken for the seasonal quarter (Dece ber-February, &c.). This seemed to be the more satisfactory course, for cause must precede the effect. Also the connection between heat a diarrhœa is perfectly well known, but the time of the highest death r from diarrhœa comes some three weeks or so later than the time of high temperature. It may be added that had the civil instead of the seaso quarter been taken the results would have been substantially the same.

The mean temperature is that of Greenwich. A more central stat would have been better, but for so long a period as three months, Greenwich temperature, considered simply as a departure from the me must be fairly representative of that of England.

TABLE SHOWING THE DEPARTURES FROM THE AVERAGE OF THE QUARTERLY DEATH R AND OF THE QUARTERLY MEAN TEMPERATURE.

Year.	Winter.		Spring.		Summer.		Autumn.	
	Death Rate.	Temp.	Death Rate.	Temp.	Death Rate.	Temp.	Death Rate.	Tem
		°		°		°		
1862	— ·9	+1·1	— ·6	+1·9	—3·1	—2·5	·0	—
1863	·0	+3·2	+1·2	+1·2	+ ·6	— ·5	— ·2	+
1864	+2·2	— ·7	+ ·7	+ ·7	+ ·3	—1·2	+1·1	—
1865	+1·2	—2·2	+ ·2	+1·2	+ ·2	+ ·5	+ ·4	+3
1866	+1·2	+2·5	+2·4	— ·9	+ ·6	— ·4	— ·6	+
1867	·0	+1·3	— ·9	— ·4	—1·2	—1·0	—1·1	—1
1868	—3·3	— ·1	—1·6	+2·7	+2·6	+3·6	— ·6	—
1869	— ·8	+4·8	— ·3	—1·0	— ·6	— ·6	+ ·5	+
1870	+ ·8	—1·8	— ·2	+ ·2	+ ·9	+1·7	— ·1	—1
1871	— ·5	—2·9	— ·5	+1·1	·0	— ·4	+1·0	—2
1872	+ ·1	+2·5	+ ·4	+ ·8	+1·8	+ ·9	— ·7	
1873	— ·5	+ ·8	— ·3	— ·9	+ ·2	+1·2	+ ·6	—1
1874	— ·1	+1·0	+ ·3	+1·0	+1·6	+ ·1	+2·8	+
1875	+4·0	—2·1	+1·4	+ ·1	+ ·9	— ·5	+ ·8	—
1876	·0	+ ·3	+ ·2	—1·2	+ ·3	+1·9	—1·1	+
1877	—1·2	+4·1	+ ·7	—2·1	—1·6	+0·5	— ·8	—
1878	— ·8	+1·8	+ ·1	+1·4	+1·4	+1·2	+1·6	—
1879	+1·5	—4·7	+ ·3	—2·8	—2·9	—2·5	+ ·1	—
1880	— ·7	—3·2	—1·0	+ ·9	+1·1	·0	—1·4	—
1881	—1·8	—1·5	+2·0	+ ·4	—2·5	+ ·3	—2·3	—
1882	·0	+1·4	— ·1	+2·4	+ ·6	—2·0	+ ·9	—
1883	+ ·8	+2·0	+1·0	—1·8	— ·3	— ·5	+ ·1	+
1884	—1·9	+2·5	— ·1	+ ·9	+2·7	+1·8	+ ·8	
1885	+ ·4	+1·2	+ ·3	—1·1	— ·5	— ·2	— ·5	—
1886	+1·5	—3·1	— ·9	— ·7	+ ·9	+ ·1	— ·5	+
1887	— ·7	—2·3	— ·7	—3·3	+ ·7	+2·5	— ·1	—
1888	— ·2	—2·3	—1·4	—2·3	—2·0	—2·4	—1·1	—
1889	—1·7	—1·0	—1·7	+ ·5	— ·3	·0	+ ·9	—
1890	+1·7	— ·5	—1·3	+ ·4	— ·3	—1·8	+ ·9	+
1891	+ ·4	—5·2	+4·5	—2·2	—1·3	—1·0	+ ·1	+
1892	+2·3	— ·5	—1·2	·0	—1·6	—1·0	—1·8	—
1893	—1·9	—1·6	+1·3	+4·6	+2·0	+2·7	+0·7	—

In the winter quarter there seems to be no fixed rule, though it has supposed that a cold winter is unhealthy and a warm winter healthy.

signs occur together, that is a + with a +, or a − with a −, twelve times, and unlike signs sixteen times, the remaining four being instances in which an exact average value occurs, which cannot be called either *plus* or *minus*. Thus out of 28 winters we have 12 exceptions to the supposed rule. The exceptionally mild winters of 1866 and 1883 were unhealthy, and those of 1863 and 1872 had an average death rate. The exceptionally cold winters of 1881 and 1893 were exceptionally healthy, and those of 1880, 1887, 1888, and 1891 had a nearly average rate. With the exception of 1813-14, 1891 seems to have been the coldest winter of this century, and the fact that such a winter had an average death rate proves that prolonged cold is not necessarily prejudicial to health. This is the more remarkable, for 1891 was notorious for the number of its fogs.

Marked instances occur in 1865, 1875, 1877, 1879, 1884, and 1886, but 1889 gives the case of a healthy winter being coincident with a rather cold one, and 1892 of an exceptionally unhealthy winter occurring with a nearly average temperature. Thus in 32 years we have six well-marked examples and five well-marked exceptions, and I think the figures justify our stating that there is no definite relation. They do, however, show that the old proverb that "a green yuletide makes a fat churchyard" is not true.

In the summer quarter there is a marked relation between the temperature and the death rate. A hot summer is always unhealthy and a cool summer healthy. We have 22 like signs occurring together and 7 unlike.

The two summers notorious for cold, viz. 1862 and 1879, are the two healthiest summers in the list. The hottest summer, 1868, is also the most unhealthy but one. Marked instances of the rule occur in 1863, 1867, 1868, 1878, 1879, 1884, 1888, 1891, 1892, and 1893, each of these being an exceptional summer accompanied by an exceptional death rate.

Every hot summer in the list has a death rate exceeding the average, and every cold summer, excepting 1882, has a death rate below the average. There are no actual exceptions to the rule, but two partial ones, viz. the healthy summer 1881 occurring with an average temperature, and the cold summer of 1882 occurring with a + death rate.

The excessive mortality in a hot summer is partly caused by the deaths by diarrhœa of children under 5 years of age, but even if all returns from this disease were excluded the rule given above would hold.

It does not seem possible to deduce from the figures even the semblance of any relation between the two quantities for the spring and autumn quarters.

The conclusions reached so far being contrary to the general opinion on the subject, it may be well to examine the figures more in detail.

In the winter quarter there are only two years in which neither quantity departs by less than 1·0 from the average. There are eleven years in which one quantity is within ·5 of the average and the other more than 1·0 away from it. There are 19 years in which both quantities differ from the average by more than ·5. Out of these 19 years 12 are favourable to the idea that a cold winter is unhealthy, and 7 are opposed to it.

In the summer quarter the corresponding numbers are 10, 8, and 17.

[illegible]

[illegible]

[illegible]

[illegible]

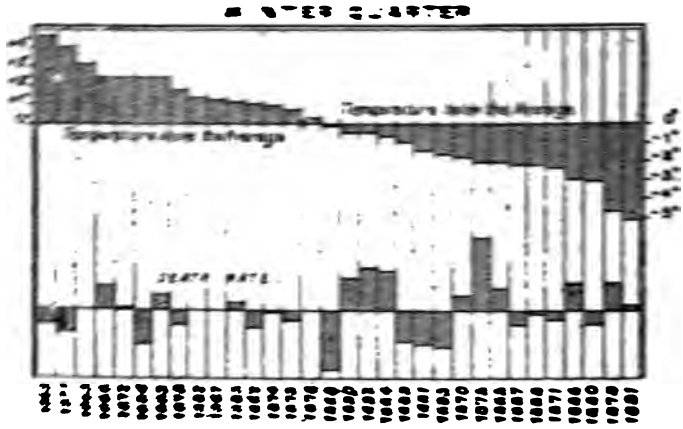


FIG. 1.

Since the lowest death rates occur in May, June, and October, and in *England the winter* death rate is much above the summer one, it has been *thought that a temperature of 50°—55°* was most favourable to life, and that *the death rate increased* in proportion to the extent to which the temperature *departed from* this value. The curves given by Dr. Buchan for New York *do not* bear this out, for though the winter temperature there is 10° below

that of London there is no corresponding increase in the death rate. It must not be forgotten that the difference between summer and winter is not only one of temperature; indeed, in England the temperature difference is trifling when compared with that of other countries; but it is also one of the duration of daylight.

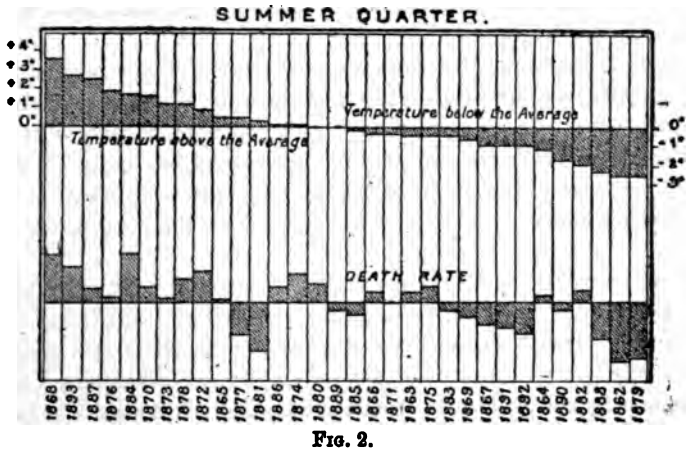


FIG. 2.

Absence of daylight means the increased use of artificial light, and in so far as the contamination of the air is concerned, one common gas burner is equivalent to four or five adults. The way in which overcrowding affects the death rate is well known; and there can be little doubt that, with the utter indifference to any proper ventilation that prevails, most of our population live in the winter in air that is greatly overcharged with carbonic acid. This is a possible explanation of the higher winter death rate, although it may perhaps be due to the direct absence of sunlight. The question is a most important one, for if my suggested explanation be correct, the general introduction of good ventilation, or the use of the electric light in the place of gas or lamps, would greatly reduce the rate, whereas if the high rate be due to temperature or the absence of sunlight owing to latitude, it is clear that no human agency can alter it.

DISCUSSION.

Dr. C. T. WILLIAMS, in a communication to the Secretary, said:—"This paper is an attempt to trace a connection between the mean quarterly temperature and the death rate, as based on the Registrar-General's returns for 82 years, and displays much ingenuity of thought, but not very reliable conclusions; for how can we judge of the effect of heat or cold without taking into consideration moisture, wind, and other elements? Again, the death rate must be analysed before any conclusions as to its connection with the weather can be drawn; for the outbreak of some epidemics of a purely contagious character will take place in any condition of the atmosphere and cause a high mortality, which should not be referred to the temperature of the air."

Dr. R. BARNES said that his experience of statistics of mortality had led him to the conclusion that unless such figures were very carefully analysed, fallacious results were likely to be obtained. There were many other considerations be-

sides that of temperature which exercised a disturbing effect on the death rate, and it was necessary to take such into account when discussing the connection between weather and mortality. Sunshine was an important factor in the preservation of health, and he was in the habit of advising his patients to "take as much sunshine as they could get." In the winter months the amount of outdoor exercise was considerably curtailed by reason of inclement weather, and there were many conditions during that season of the year which served to make the winter more unfavourable to health than the summer. He called attention to the papers of Dr. Buchan and Mr. Latham as especially valuable in this relation.

Dr. A. BUCHAN said that, considering the paucity of data, considerable ingenuity had been shown in the manner in which the material had been handled. It was probable that much better results would have been obtained if the deaths from the various diseases had been dealt with. A hot summer was always attended with an excess of deaths from diarrhœa and bowel complaints, but a great deal of winter mortality was due to sudden changes of weather and indiscretion in the matter of changing and putting off garments. The most unhealthy winter weather was usually when the temperature ranged between 32° and 40°, the climatic conditions being of that description usually spoken of as "raw," and giving rise to affections of the throat. When the weather was dry and frosty with a low temperature, good health generally prevailed, the sharpness of the cold serving to stimulate the body and impart a generally healthy tone. It would have been a better plan for Mr. Dines to have made the temperature quarters and the death rate quarters synchronous, instead of commencing the temperature period a month earlier than the death rate period. The proverb that "a green yuletide makes a fat kirkyard" appeared to be intended to apply to those seasons when the weather previous to Christmas had been mild, as such weather was frequently followed by a sudden change to cold early in the ensuing year, and a large mortality usually resulted from the advent of sudden cold after a warm period. Hot weather in summer was most fatal to young children and old people, but the outdoor life possible in the summer season tended to increase health.

Mr. F. J. BRODIE said that there was no one who had at all studied the subject of the connection between weather and health but would agree that a mild winter and a cool summer were the best from a hygienic point of view, and that as a general rule the most "unseasonable" seasons were the most healthy. But while the conclusions which Mr. Dines had arrived at were correct, the method of dealing with the statistics embodied in the paper was not quite satisfactory. For instance, the average quarterly temperature at Greenwich was compared with the average quarterly death rate for the whole of England, but it was well known that the temperature of a season over even so small an area as England varied greatly in different localities. During the winter which had just ended (December 1893 to February 1894) the temperature in England SW, as given in the *Weekly Weather Report* published by the Meteorological Office, was 0°·1 below the average, but in England S it was 0°·7 above the average, and in England NW, the temperature exceeded the average by as much as 1°·5; so that to take the temperature at one place and compare it with the death rate for the whole of England was an objectionable method. It was to be regretted, too, that the quarterly averages of temperature and mortality were for different periods. He (Mr. Brodie) had tabulated statistics of the death rate and temperature in London for several years past, and found that, owing to the different methods of working, there were considerable discrepancies between his own results and those given in the paper. In several cases a season which was said to be healthy or unhealthy over England generally was the very reverse in the metropolis, the locality from which Mr. Dines had derived his temperature values. A striking instance of this occurred in the winter of 1890-91. In the paper this is quoted as a winter with an average death rate, but in London the total mortality was 8 per cent. above the average, while the deaths from diseases of the respiratory system were as much as 33 per cent. above the average. There was at the time no epidemic of influenza, and the unhealthiness of the season might therefore fairly be attributed to the persistent low temperatures and to the undue prevalence of fog.

Dr. W. MARCET said that he agreed with Mr. Brodie in his objection to the

average temperature of Greenwich being compared with the death rate of the whole of England, as there were often great variations in the weather in even one season over different parts of the country. During the winter of 1890-91 the weather was very severe in the south of England, and the cold was prolonged over several weeks, but in Scotland he believed the weather was wetter and warmer than the average. There was no doubt that very cold weather killed a number of old people, and that extremes of temperature increased the death rate. It would be interesting to know, in view of Dr. Nanssen's expedition to the North Pole, what the effect of a term of years spent in Arctic temperatures would be upon the human body. He heard it stated by the monks at the Hospice on Great St. Bernard (8,000 feet above the sea), who were all young men of strong constitution, and selected as best fitted to endure the rigorous climate, that most of them suffered in health after living a year on the mountain, and after two or three years' stay were unable to remain any longer.

Mr. G. J. SYMONS said that in comparing death rate and temperature he did not think it was desirable to adopt identical months, as there must be some interval between the weather influence and the entry of the deaths ensuing from it. Moreover, Mr. Dines had evidently taken identical quarters as well as the meteorological quarters, as he says, "It may be added, that had the civil instead of the seasonal quarter been taken, the results would have been substantially the same."

Mr. W. H. DINES, in reply, said that his only knowledge of the subject was contained in the table he had given, and in the deductions that might fairly be drawn from it. With reference to Dr. Williams' and Dr. Barnes' remarks as to sunshine and moisture, he did not think that moisture, considered simply as the amount of rainfall, made much difference; and he believed that others who had worked at the subject had come to the same conclusion. With regard to sunshine, he had no figures showing its prevalence since 1862; but it would require very strong evidence to make him suppose that sunshine could be anything but favourable in the winter. It was different in the summer; and if it was then healthy, its effect was completely overmastered by the accompanying heat. Thus the dull, gloomy summers of 1879 and 1888 had been very healthy, but the almost uninterrupted sunshine of 1868, 1884 and 1893 had given the three highest death rates in the list. With reference to epidemics, he thought that they were seldom widespread enough to greatly influence the returns from a population of 25 millions, and that the few instances in which they had done so were unimportant, when taken in connection with a period of 32 years. He thought that Dr. Buchan's remark that a temperature between 32° and 40° was the worst to be very probable, and further investigation might show that this explained the figures for the winter months. Certainly it applied to 1891, in which the unusual phenomenon of some six weeks with a temperature below 32° had occurred. He agreed with Mr. Brodie in thinking that the more unseasonable the weather the more healthy, if unseasonable meant a mild winter and a cold summer. He had taken the Greenwich temperatures because they were so easily obtained; no doubt the differences from the average at Greenwich were not always the same as the differences in other districts, but on the whole he thought they were fairly representative of England, excluding of course Scotland and Ireland. He had taken the whole country, and not London only, for the death rate, because accidental variations, due to a local epidemic, or a period of London fog, for example, would be more likely to be eliminated. As a general rule the town and country death rate rose and fell together, although Mr. Brodie had instanced one case, namely the summer of 1882, in which they did not do so. His plan of taking different periods had been criticised; but, as Mr. Symons had pointed out, he (Mr. Dines) had taken the trouble to ascertain that the conclusions reached would have been the same if the other plan had been adopted. He had, when preparing the paper, been in considerable doubt on the point, but had been chiefly influenced by the returns relating to diarrhœa. Mr. Symons had given another reason, which had not previously occurred to him. In conclusion, he said that he thought that the death rate curve for the winter quarter appeared to have no connection with the temperature curve, but that the steady slope of the summer curve from left to right showed plainly the deleterious effects of heat and the beneficial effects of cold.

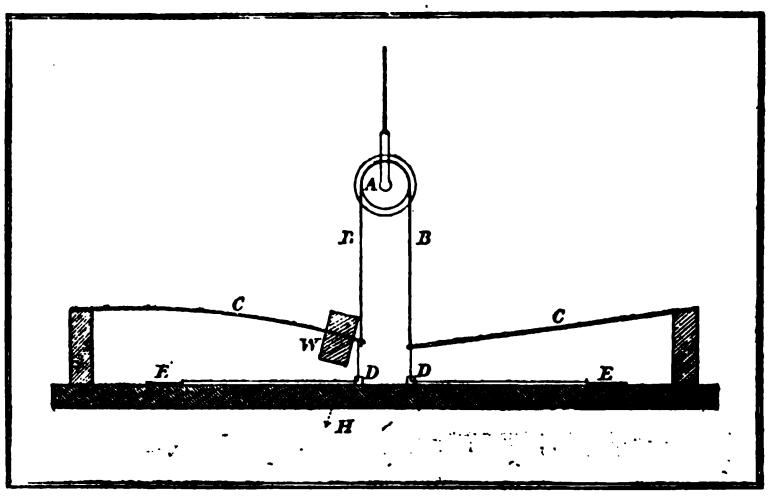
On the Duration and Lateral Extent of Gusts of Wind and the Measurement of their Intensity.

By W. H. DINES B.A., F.R.Met.Soc.

[Received February 21st.—Read March 21st, 1894.]

The Royal Commission appointed to inquire into the Tay Bridge disaster recommended that in similar structures allowance for an extreme wind pressure of 56 pounds per square foot should be made. This estimate seems to have been based on the automatic records of the pressure given by the Osler pressure plate at various observatories, but it is thought by some engineers, who are well qualified to form an opinion, that such high pressures as 56 lbs. per square foot do not occur in England. As a matter of fact much higher pressures have been recorded, and the whole question reduces itself to this: How much reliance can be placed on the correctness of the instruments?

In my opinion the attempt to obtain a record of the mean pressure and also of the maximum pressure by the same instrument is hopeless, and



I now proceed to give an account of some experiments and observations which show that the maximum pressure given by the ordinary spring plate depends far more upon what may be called the "personal equation" of the instrument than upon the force of the wind.

An extremely light pulley, *A*, was fastened to the end of the cord coming from a foot circular pressure plate. A string, *BB*, was placed over the pulley, the ends of which were fastened to two exactly similar springs, *CC*.

The springs were formed of tempered steel, of about $\frac{1}{8}$ by $\frac{3}{8}$ section, and 1 foot long, one end of each being rigidly fixed. One spring was loaded at the moveable end by a 2lb. weight, *W*.

The maximum deflexion of each spring was recorded by tying a piece of cotton to the free end, passing it under a staple, *D*, and attaching a light aluminium index, *E*, to the other end. On raising the spring the index is drawn over a horizontal scale, and it, of course, does not return when the spring is released. The scales were made by applying definite weights and noting the position to which the indices were drawn. They were found to be exactly alike, and were carefully checked from time to time.

From the form of this apparatus it is clear that a force applied with any approach to steadiness must give the same result upon both scales. The actual results obtained from observations made during the past winter are shown in Table I., the first column giving the value from the loaded spring and the second column the simultaneous value from the unloaded spring.

A glance at these figures shows how greatly the momentum of a pressure plate influences the maximum pressure which it records. It can be shown mathematically, or by direct trial upon the apparatus, that a sudden jerk, the force not being sustained even for an instant, causes the unloaded spring to give the higher value; but that a jerk, the force being sustained even for a second, causes the loaded spring to give the higher value.

Neglecting the "moment of inertia" and friction of the pulley, we see from elementary mechanical principles that the forces applied to each spring are always equal; yet the differences of the deflexions produced are sometimes as great as 50 per cent.

It would appear from the figures in Table I. that the heavier a plate is the more likely it will be to give too high a value, for as a rule the loaded spring shows an excess over the unloaded.

It is also worthy of note that the weight attached to the spring produced quite a dent in the wooden frame of the apparatus at *H* by hammering against it; although it required a downward force of 1 lb., equivalent to a negative pressure of 2 lbs. on the plate, to make it touch the wood. A thrust cannot be transmitted through a flexible cord, hence the dent could only be caused by the oscillation of the spring; and if it often swung below its zero position, it follows inevitably that it must often also have gone the same distance too far on the other side.

It is possible that the aluminium indices were sometimes jerked into a position not warranted by the deflexion of the spring, but this would be more likely to happen with the one in connection with the unloaded spring than with the other. If so, it still more confirms my opinion as to the unreliability of the records. It is very probable that this jerking of the pen and pen carriage is the true explanation of the enormous pressures that are recorded. It is remarkable that Bidston Observatory is famous for high pressures, and, if the traces given in the Tay Bridge report are exact copies, the scale at Bidston is the shortest, and consequently, if the pencil is jerked an inch or so too high, it will have more effect on the record there than elsewhere.

The difficulty of measuring a rapidly varying quantity is not confined to meteorology, but in other branches of science the instruments used for this purpose are designed so that they may be adapted for the work they have to do. The indicator diagram of a steam engine, for example, would not, I imagine, be of much value if the diagram were drawn by an apparatus similar to the ordinary recording pressure plate: yet the variations of wind force seem to be almost as rapid as the variations of the steam pressure in the cylinder of a steam engine.

I think that the momentum of the plate itself often adds 30 to 50 per cent. to the real pressure, and that the sudden jerk transmitted through the chain or wire often brings the pen or pencil another 50 per cent. above its proper place. Mr. Ellis has told us how substituting a flexible chain for a wire reduced the Greenwich pressure, and it is not unreasonable to suppose that if the chain also had been done away with, and the clock and drum placed close behind the plate, a still greater reduction might have occurred.

The pressure plate is a most useful anemometer and gives most interesting results, including a perfectly accurate mean pressure. If it were provided with a rack and catch, so that it could not oscillate, but once driven back by the wind could not return until set by the observer, the record of the mean would be lost, but the record of the maximum would be reliable.

TABLE I.—IDENTICAL MAXIMUM PRESSURES REGISTERED BY LOADED AND UNLOADED SPRINGS.

Loaded Spring.	Unloaded Spring.	Per-centage.	Loaded Spring.	Unloaded Spring.	Per-centage.	Loaded Spring.	Unloaded Spring.	Per-centage.
lbs. per sq. ft.	lbs. per sq. ft.		lbs. per sq. ft.	lbs. per sq. ft.		lbs. per sq. ft.	lbs. per sq. ft.	
3·2	3·0	107	7·0	6·4	109	7·2	6·2	116
4·8	2·8	171	7·4	5·0	148	10·1	6·2	163
2·4	2·0	120	7·0	8·2	85	4·8	3·6	133
2·0	1·4	143	12·0	7·5	160	7·8	8·0	97
5·2	4·4	118	9·0	6·6	136	5·2	4·2	124
8·8	6·2	142	4·2	4·4	95	8·8	4·8	184
10·0	7·6	132	6·1	5·0	122	17·6	8·6	204
8·0	7·0	114	14·1	8·5	165	5·8	4·4	132
4·8	5·2	92	18·0	15·0	120	6·0	4·6	130
4·8	4·0	120	7·0	5·2	135	3·8	2·8	136
4·8	5·2	92	7·0	9·6	73	10·0	11·2	89

The preceding results give no information as to the duration of the gusts, but only show the great suddenness of the variations. For this purpose the tube anemometer has been used. This instrument has been described before,[1] and the description need not be repeated. The maximum recorded depends just as much on the particular instrument as it does with the pressure plate, but by contracting the tube which holds the liquid, or either of the pipes which transmit the pressure from the head, it can be damped in a very convenient way.

[1] *Quarterly Journal*, Vol. XVIII., p. 168, and Vol. XIX., p. 17.

Two similar glass tubes were obtained and bent to exactly the same curve. They were partly filled with coloured paraffin oil and fixed on a frame side by side touching each other, with a velocity scale underneath. The ends of the tubes being connected with the head of the anemometer, the two columns of coloured oil moved up and down together, registering exactly the same maximum velocity for each gust of wind. A piece of tube of $\frac{1}{32}$ in. bore and about 3 inches long was then inserted between one tube and the head, the other being left as before. The maxima recorded for the same gust by these two tubes are given in Table II.

TABLE II.—Maximum Velocities registered by Open and Contracted Glass Tubes worked by the same head.

Open Tube.	Contracted Tube.	Open Tube.	Contracted Tube.	Open Tube.	Contracted Tube.	Open Tube.	Contracted Tube.
Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.
27	22	37	31	41	39	55	53
31	27	43	33	48	44	44	40
29	25	32	30	50	49	53	45
19	15	33	31	50	48	54	46
28	24	44	41	45	42	63	58
34	27	22	22	53	49	72	68
30	26	56	52				

A large number of observations have been made, and they all present differences similar to those given in the table, which have been taken just as they came and not selected in any way.

I really used five tubes, but since it soon appeared that the maximum registered was strictly proportional to the amount of damping brought into play, the observations from the intermediate tubes were discontinued. The figures given refer to the two extremes.

It was found by experiment that the sudden application of a pressure corresponding to 40 miles per hour, the tubes then indicating zero velocity, produced the following effects:—

The liquid in the open tube rose to 43—44, owing chiefly to its momentum, but partly because some little of it remained sticking to the glass, there not being time for it to settle to its true level. The liquid in the damped tube rose steadily, it never exceeded the 40 miles per hour, but took from five to six seconds to reach that value.

We do not know how the gusts rise, so we cannot imitate them artificially, but during a gale in which the maximum velocity, as registered by the open tube, is about 60, the minimum will not as a rule fall below 20.

The motion of the liquid during such a gale, which has occurred twice this winter, viz. on December 12th and February 11th, is most interesting. It consists of a perpetual oscillation between the limits of about 80 and 50, sometimes rising and falling steadily, and sometimes by sudden jerks. So

far as I have observed, however, an upward jerk is hardly ever followed instantly by a downward jerk.

It appears from Table II. that the extreme force of the wind is hardly ever maintained steadily for so long as five seconds. If it were the two tubes would give maxima much nearer together. Also since the damped tube never falls so low as the other, it has not so far to rise, and would not take nearly five seconds to reach its maximum; hence I am inclined to think that a gust seldom maintains its full force for more than one or two seconds.

It must be remembered that in Table I. pressures are given, and velocities in Table II. Since the pressure varies as the square of the velocity, the percentage difference of the pressure deduced from Table II. will always be more than double the percentage difference of the velocities.

The same two glass indicating tubes were used to determine as far as possible the lateral extent of the gusts. Neither of them was damped, and they were connected with two separate but exactly similar anemometers, placed at the same height, viz. 18 ft., but 11 ft. apart, over the top of my house.

The maxima given by the tubes for the same gust are shown in Table III.

TABLE III.—MAXIMUM VELOCITIES REGISTERED BY TWO TUBE ANEMOMETERS PLACED 11 FEET APART.

North-west Anemometer.	South-east Anemometer.	North-west Anemometer.	South-east Anemometer.	North-west Anemometer.	South-east Anemometer.	North-west Anemometer.	South-east Anemometer.
Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.	Miles per hour.
51	54	72	75	55	55	36	45
43	44	50	47	47	47	52	50
43	48	47	44	42	40	56	56
55	62	56	55	48	47	41	49
53	50	47	50	48	38	51	49
53	53	58	56	43	43	53	49
63	65	48	50	31	35		

It will be seen from the figures that even at so short a distance as 11 ft. apart the extreme force exerted is sometimes very different, but this is more fully borne out by direct observation of the instruments during a strong wind. It is perfectly apparent that the gusts often, in fact generally, strike the heads of the anemometers at different instants, and it often happens that the liquid in one tube is rising while that in the other is falling.

The tubes were interchanged several times, but the exact similarity of the two instruments, and the fact that sometimes one and sometimes the other gives the actual maximum, shows that the differences could not possibly be due to the instruments, but must be a real phenomenon.

One anemometer was south-east of the other, and the differences are always greatest with a South-west or North-east wind, in fact with a South-

east wind the two columns of liquid often move together as though they were rigidly connected. From this I gather that the extreme velocity mostly occurs in lines which are roughly parallel to the direction of the wind.

It would be very interesting to carry this investigation further, but the conditions of exposure do not render it possible for me to do so at Oxshott. It is apparent to any one who carefully watches the motion of the trees in a gale that the gusts are of no great extent laterally. It is impossible to indentify the gusts that pass over a prominent poplar tree about 300 yards from any sitting room window with those that agitate the nearer trees.

I am quite aware that at an exposed coast station the wind is not so gusty as it is inland, but the traces given by the bridled anemometer at Holyhead certainly do not lead to the conclusion that it is at all steady even there. In this anemometer there is no chain or wire, the pencil being rigidly connected with the cups to which the wind pressure is applied. As a result, velocities which give a pressure exceeding 30 lbs. per square foot are extremely rare, although the recent gale in this neighbourhood, which gave a pressure of 37 lbs. at Greenwich, would probably by comparison have been but a gentle breeze to the gale of November 18th-19th, 1893, at Holyhead.

The late Mr. Hawksley, at one time President of the Institution of Civil Engineers, is stated to have said that "the instruments at present in use are little better than philosophical toys, and that in general they afford no direct comparable or reliable indications of either velocities or pressures."[1] So far as velocities are concerned, I hope this is not true now, although we still print all our records of velocity without comment, knowing the amount given is some 30 per cent. too high; but so far as records of maximum pressure are concerned, I do not myself think they are worth more than the paper on which they are printed.

DISCUSSION.

Mr. W. AIRY said that he so entirely agreed with Mr. Dines's conclusions that he had no criticism to offer upon the paper. He was fully in accord with Mr. Dines's statement that "the attempt to obtain a record of the mean pressure and also of the maximum pressure by the same instrument is hopeless." The maximum pressures recorded by the Osler pressure plate were too great, although no doubt the instrument recorded the mean pressure accurately. But while the mean pressure was of some value, the maximum pressures were the most important and useful, as it was those which caused damage to structures. He had noticed that the Osler pressure plate never really faced the wind when struck by a gust, the gust appearing to have the effect of making it oscillate sideways, so that the full force of the wind did not act upon the plate. Sir John Fowler had deputed to him the arrangement of the anemometers for the Forth Bridge experiments, and he erected two anemometers, one fixed with its front in the direction from which the strongest winds usually came (a little South of West), and the other moved by a vane. He predicted that the greatest pressure would be recorded by the fixed anemometer, and the results fully bore out his expectations. In connection with the Forth Bridge it was important to test the lateral extent of gusts, and for this purpose a large pressure plate 20 feet by 15 feet was constructed. It being too heavy and awkward a thing to attach to a vane, it was fixed in a similar position to that of the small fixed anemometer,

[1] *Quarterly Journal*, Vol. VIII., page 29.

and he believed it was found that the maximum pressures per square foot on this 800 feet area were about two-thirds of those registered by the small plates. It would be interesting if Sir John Fowler would publish the results of the observations that were made with these pressure plates. The lateral extent of wind gusts was an important factor, and one that it was desirable to know in order to ascertain the amount of pressure exerted over a large area of ironwork, such as the Forth Bridge; but the sea appeared to be the only suitable place for making such observations. Some interesting particulars bearing on this point were given by Capt. Watson in a letter which he (Mr. Airy) had received when Secretary of the Tay Bridge Commission. Regarding the duration of gusts, he (Mr. Airy) had never observed a violent gust which maintained its maximum pressure for so long a time as one second.

Mr. R. H. CURTIS said that Mr. Dines had again referred to what was without doubt a grave fault in Osler's pressure plate anemometer, namely, the tendency of the momentum of the plate to exaggerate the record; but he thought a still more serious, because at present still less understood, drawback to the instrument lay in the fact that it was impossible to compare *inter se* the records of instruments which differed as to size and shape of plate. Experiments which he had himself made with plates of different areas and shapes showed that the stream lines on their surfaces varied very greatly with changes in both directions, and from these and other facts he concluded that the pressure per unit of surface must certainly be less on large than on small plates. This fact, combined with the errors due to momentum, and—in some cases at any rate—others due to arrangements adopted for conveying the movement of the plate to the pencil, made the records from this form of instrument unreliable. With reference to the lateral extent of gusts, he could not agree entirely with Mr. Dines's conclusions. It was very evident that in the neighbourhood of trees and houses the currents of air must become much broken up, and under such conditions they would be very different from what they would be at sea, or on a perfectly open plair. Mr. Dines's vanes were placed upon the roof of a house, with gables and a roof which sloped from the walls up to a flat top, and the country round is undulalating and well wooded; under such conditions eddies would be numerous and inevitable, and it would be impossible to predict their character or extent. Anyone watching squalls travelling over the surface of the sea or of a large sheet of water, would notice that while they generally cover a considerable extent of surface, in some cases they are very extensive indeed. Then, with respect to the duration of gusts, he was also unable to endorse what had been said by Mr. Dines and Mr. Airy. It was a point to which he had given a great deal of attention for many years, and lately he had spent a good many hours by the side of Mr. Dines's pressure tube anemometer, watching the action of the pen in squalls of wind. That instrument entirely confirmed what he had previously observed, namely, that gusts of wind rarely come on with their full force all at once, but by a succession of steps or pulses, and he had certainly often noticed the pen to remain at its highest point for longer periods than had been mentioned.

Mr. R. W. MUNRO inquired whether Mr. Airy could state the difference in weight per square foot between the large and small pressure plates used at the Forth Bridge Works.

Mr. W. AIRY said that he was unable to give the figures asked for by Mr. Munro off hand, but the difference was considerable.

Mr. W. H. DINES, in reply, said that he considered that the maximum pressure was the most important, but he was certain that it could not be obtained from a plate that was free to oscillate. He had found that in certain cases the wind pressure was greater when the air struck the plate at an angle than when it struck it perpendicularly, and this might perhaps explain why Mr. Airy had sometimes obtained the greatest pressure on a plate which could not turn to the wind. His experiments had also shown that the greater the plate the less proportionally was the pressure upon it. He agreed with Mr. Airy in thinking that the greatest force was often not maintained even for a second, but it did not necessarily follow that Mr. Curtis was wrong in his belief, for some gusts might not last for a second, while others might maintain their full force for five seconds. This appeared from Table II., which gave some instances of close agreement between the two tubes, thus showing that the gust lasted some few

seconds. Replying to Mr. Curtis, he said that his two anemometers were 18 ft. above the ridge of the house, and he was inclined to think that they were high enough to be free from eddies.

ON THE CALCULATION OF PHOTOGRAPHIC CLOUD MEASUREMENTS.

By Dr. K. G. OLSSON,

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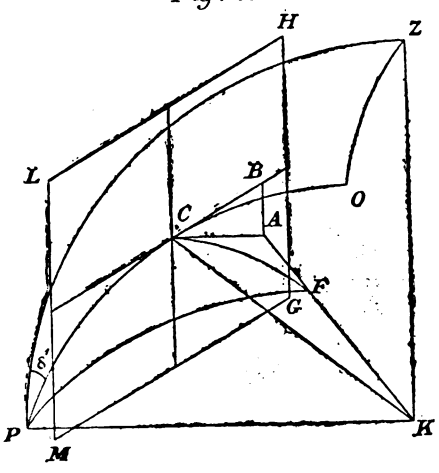
[Received December 27th, 1893.—Read March 21st, 1894.]

In consideration of the importance which measurements of the height and motion of clouds have obtained in recent times, I have, at the request of Dr. N. Ekholm, undertaken to develop formulæ adapted to the computation of photographic cloud measurements. Because, with observations of this kind, the photographic plate takes up so vast a field of view, that approximative formulæ giving the requisite precision cannot be used except for those parts of the image near to the optical axis, exact formulæ must be deduced by solving the spherical triangles and must then be brought into a form convenient for numerical work. In the first place formulæ will be given for measurements with the "cloud equatorial," described by Dr. N. Ekholm,[1] and then, shortly, formulæ applicable for instruments of the theodolite type.

Fig. 1.



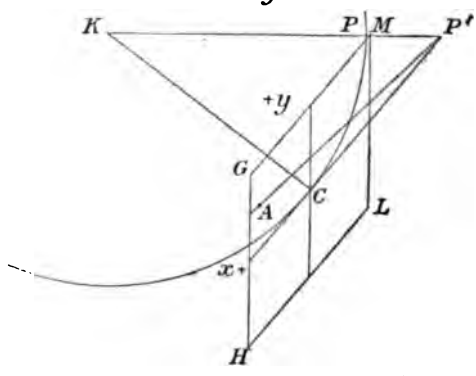
1. Let a sphere of arbitrary radius (Fig. 1) be drawn so that its centre K coincides with the centre of the photographic object glass, and let a tangent

[1] *Quarterly Journal.* Vol. XIX. p. 38.

plane $GHLM$ of this sphere be drawn, touching it in the point C, where the optical axis KC meets its surface, then all the photographed objects will be projected in this tangent plane. Also, provided the object glass be good and the plate exactly perpendicular to the optical axis, the image on the photographic plate will be a projection perfectly similar to the former. Supposing this to be so, let POZ represent a part of this sphere, P being the point where the axis of the instrument, when produced, meets the surface of the sphere, the "pole" of the instrument say, and KZ the vertical line. Let A be the point in the tangent plane, the spherical coordinates of which are to be determined, and F the point, where KA meets the spherical surface, then the arc $PF = \alpha$ and the spherical angle $FPZ = \delta$ are the coordinates sought. I suppose α to be reckoned from KP upwards from 0° to 180°, and δ from 0° to +90° or −90° on each side of the vertical plane KPZ of the instrument. The arc $PC = \alpha'$ say, and the spherical angle $CPZ =$ the arc $OZ = \delta'$ say, will be found by reading the circles of the instrument, and may, of course, be considered as known. Then a system of coordinates must be drawn in the photograph with its origin in the image point corresponding to C, and the coordinates of the image point of A must be measured on the plate. Thus, the problem will be to compute α and δ by means of α' and δ' and those coordinates.

2. For this purpose, let (Fig. 2) K represent the inner principal point of the object glass. Then, to the tangent plane $GHLM$ in C (Fig. 1) corresponds the photographic plate $GHLM$ (Fig. 2). If then a sphere be drawn

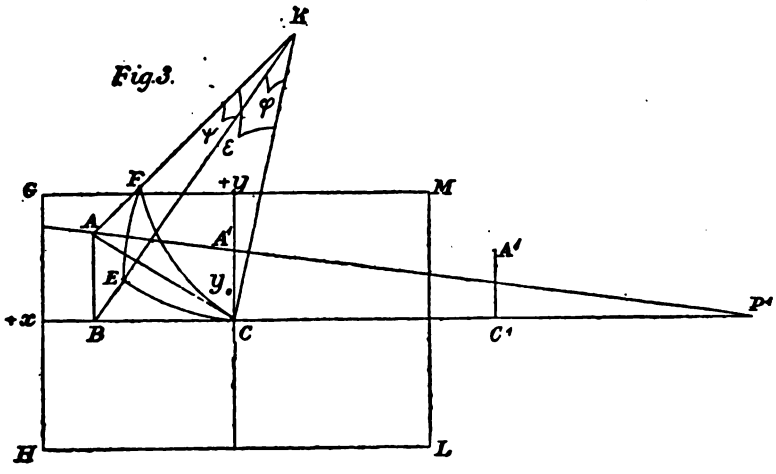
Fig 2.



through C with its centre in K, it will touch the photographic plate in C, and if the straight line KP be drawn from K parallel to the axis of the instrument, the point P corresponds to the "pole" of the instrument (P in Fig. 1). The great circles drawn through P will be projected, as will be shown below, as straight lines on the photographic plate, and they will all meet in the point P' where KP produced meets the plane of the photographic plate. The dihedric angle formed by any great circle with the vertical plane will represent a value of δ, and the corresponding values of α will be

measured along the periphery of the great circle from P downwards. Thus we may conveniently call them "α-great circles."

8. Now let (Fig. 8) the photographic plate be laid in the plane of the paper, the line CK being directed upwards, and then, taking C as the origin, let two axes of rectilinear coordinates be drawn perpendicularly in such a way, that the axis of x touches the α-great circle of the sphere, the positive directions being taken so that x is increasing with α and y with δ; thus $CB=x$ and $BA=y$ will represent the coordinates of A in this system. If an apparatus for measuring polar coordinates be employed, $AC=r$ and the plane angle $ACB=\Theta$ are the corresponding coordinates, where, of course, Θ ought to be reckoned from the left to the right, viz. from the positive x-axis to the positive y-axis. Now let us introduce the auxiliary angles $BKC=\phi$ and $AKB=\psi$, and, moreover, for the second case (polar coordinates) $AKC=\varepsilon$.



Method I. Rectangular coordinates.

The plane ABK meets the sphere drawn through C with its centre in K along the arc of great circle EF and the plane BCK along the arc EC. Thus the arc EF is $=\psi$ and the arc $CE=\phi$. The triangle BCK, rectangular at C, gives, if CK be put $=k$, k being an instrumental constant,

$$x=k\tan\phi \quad \ldots \quad \ldots \quad (1)$$

From the same triangle we obtain

$$BK=\frac{CK}{\cos\phi}=\frac{k}{\cos\phi}$$

and from the triangle ABK, rectangular at B,

$$y=AB=BK\tan\psi$$

by which

$$y=\frac{k\tan\psi}{\cos\phi} \quad \ldots \quad \ldots \quad (2)$$

By means of (1) and (2) ϕ and ψ can be computed.

Method II. Polar coordinates.

The plane ACK (Fig. 3) intersects the sphere along the arc of great circle FC, thus the arc FC is $=\epsilon$ and the spherical angle ECF is $=\Theta$. The triangle ACK, rectangular at C, gives

$$r = k \tan \epsilon \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

from which ϵ can be calculated. Then the spherical triangle CEF, rectangular at E, gives:

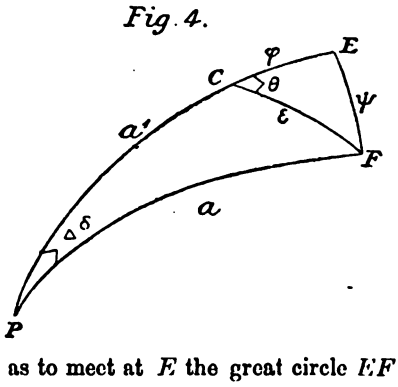
$$\left.\begin{aligned} \sin\psi &= \sin\epsilon \sin\Theta \\ \cos\psi \sin\phi &= \sin\epsilon \cos\Theta \\ \cos\psi \cos\phi &= \cos\epsilon \end{aligned}\right\} \quad \ldots \quad \ldots \quad (4)$$

by which

$$\left.\begin{aligned} \tan\phi &= \tan\epsilon \cos\Theta = \frac{r}{k}\cos\Theta \\ \tan\psi &= \tan\Theta \sin\phi \end{aligned}\right\} \quad \ldots \quad \ldots \quad (5)$$

4. Now let the superficial triangle CPF in Fig. 4 be the same triangle as CPF' in Fig. 1, separated from the rest, and let the arc of great circle

Fig. 4.



PC be produced so as to meet at E the great circle EF drawn from F perpendicular to PC, then again we find $EC = \phi$ and $EF = \psi$. Also, putting

$$\Delta\delta = \delta - \delta'$$

we obtain from the rectangular spherical triangle EFP,

$$\left.\begin{aligned} \sin\alpha \sin\Delta\delta &= \sin\psi \\ \sin\alpha \cos\Delta\delta &= \cos\psi \sin(\alpha'+\phi) \\ \cos\alpha &= \cos\psi \cos(\alpha'+\phi) \end{aligned}\right\} \quad \ldots \quad \ldots \quad (6)$$

from which

$$\left.\begin{aligned} \tan\Delta\delta &= \frac{\tan\psi}{\sin(\alpha'+\phi)} \\ \tan\alpha &= \frac{\tan(\alpha'+\phi)}{\cos\Delta\delta} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (7)$$

Here it must be observed that, for the numerical calculation, it is not

necessary to know ψ, but only tan ψ, and therefore the first of the formulæ (7) is more suitably written in the following manner :—

$$\left.\begin{aligned} \text{I.}\quad \tan \Delta\delta &= \frac{y \cos \phi}{k \sin (a' + \phi)} \\ \text{II.}\quad \tan \Delta\delta &= \frac{\tan \Theta \sin \phi}{\sin (a' + \phi)} \end{aligned}\right\} \quad \ldots \quad \ldots \quad (8)$$

where I. is to be used for rectangular coordinates and II. for polar ones.

The above formulæ are developed for the one of the two cloud equatorials, but can immediately be applied also for the other, if everywhere a is changed in β (compare Dr. Ekholm's formulæ (1)). Thereby it is to be observed, because the angles a and β are taken in opposite directions, and as the positive axis of x is drawn in the same direction as a increases, that the two photographic plates are symmetrically equal, viz. if they be laid with the positive y-axis in the same direction, the positive x-axis will lie in opposite directions, and consequently also the angle θ must be reckoned from the positive x-axis in opposite directions.

5. In his paper "A new instrument, etc." Dr. Ekholm indicates the advantage of being able to draw corresponding lines on the two photographic plates. Those are evidently each pair of lines, for which the coordinate δ is the same, and, as now will be shown, those lines are straight. For in Fig. 2 let a plane turn round KP, then the sections between this plane and the sphere will be the a-great circles, and accordingly, the images of all the objects, that have the same δ, must all lie in the straight line, along which the turning plane intersects the plane of the photographic plate. In order to construct those lines, let us cut off from C on the axis of x a length (Figs. 2 and 3)

$$CP' = k \tan a' \text{ (the numerical value)}$$

in the negative direction, if $a' < 90°$, and in the positive direction, if $a' > 90°$. Then, according to Fig. 1, the angle $CKP =$ the arc $CP = a'$, and thus the projection of CP on the tangent plane will be

$$KC \tan a' = k \tan a'$$

so that P' will be the point where all these straight lines meet. Thus if the photographic plate be fastened on a drawing table, these lines (for instance AP' in Fig 3) may be drawn with a rule. If CP' be so great that the point P' cannot be conveniently employed for the construction of the lines AP', which may be the case for a' between 80° and 100°, a scale (C_1A_1) drawn perpendicularly to CP' in a point (for instance $C_1 = \frac{1}{2} CP'$) may be employed instead of P'.

This proceeding may also be applied in order to obtain a third method for determining $\Delta\delta$.

Method III.

Let $CA' = y_0$ (Fig. 3) be the part of the axis of y cut off by any of the lines $l''A$. Then an expression for y_0 can be found in the following manner.

In Fig. 2 let a plane be laid through C and the axis of y (or CA') perpendicular to KP, and let it cut KP in H (Fig. 5). The triangle $A'CH$, rectangular at C, gives, the angle $A'HC$ being $= \Delta\,\delta$,

$$y_o = A'C = CH \tan \Delta\,\delta$$

but

$$CH = KC \sin \alpha' = k \sin \alpha'$$

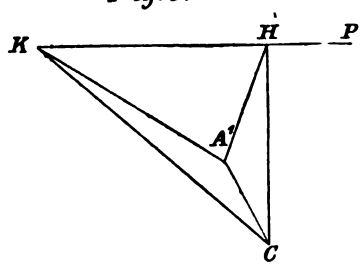
thus

$$y_o = k \sin \alpha' \tan \Delta\,\delta$$

from which

$$\tan \Delta\delta = \frac{y_o}{k \sin \alpha'} \quad \ldots \quad \ldots \quad (9)$$

Fig. 5.



In order to find the corresponding line on the other plate, we have :—

$$y_o' = k' \sin \beta' \tan \Delta\,\delta,$$

k' being the instrumental constant of the other instrument, analogous to k for the first. As then the quotient

$$\frac{y_o'}{y_o} = \frac{k' \sin \beta'}{k \sin \alpha'}$$

is a constant for the two plates, the corresponding lines are easily drawn.

For an instrument of the theodolite type P' is the image on the plane of the photographic plate of the zenith point, and the straight lines AP' are the images of the vertical circles. As, however, the two instruments are deprived of the advantage, that exists in the cloud equatorial, of having a common plane, these lines have not the quality, that one of the coordinates, which are to be determined, is the same for all the objects that lie on two corresponding lines.

6. If the formulæ above given are combined, the scheme will be as follows :—

Method I. Measuring of the rectangular coordinates x and y on the photographic plate :

$$\tan \phi = \frac{x}{k}\,;\ \tan (\delta - \delta') = \frac{y \cos \phi}{k \sin (\alpha' + \phi)}\,;\ \tan \alpha = \frac{\tan (\alpha' + \phi)}{\cos (\delta - \delta')} \quad \ldots \quad (10)$$

Method II. Measuring of the polar coordinates r and Θ :

$$\tan \phi = \frac{r \cos \Theta}{k}\,;\ \tan (\delta - \delta') = \frac{\tan \Theta \sin \phi}{\sin (\alpha' + \phi)}\,;\ \tan \alpha = \frac{(\tan \alpha' + \phi)}{\cos (\delta - \delta')} \quad (11)$$

Method III. Graphical construction of the α-great circles and measurement of x and y_o :

$$\tan(\delta-\delta')=\frac{y_o}{k\sin a'};\ \tan\phi=\frac{x}{k};\ \tan\alpha=\frac{\tan(a'+\phi)}{\cos(\delta-\delta')}\quad\ldots\quad(12)$$

With regard to the determination of the quadrants in which the angles ought to be taken, we observe that ϕ lies between $-90°$ and $0°$, when x or $\cos\Theta$ is negative, and between $0°$ and $+90°$, when x or $\cos\Theta$ is positive; that $\Delta\delta$ lies between $-90°$ and $0°$, when $\tan\Delta\delta$ is negative, and between $0°$ and $+90°$, when $\tan\Delta\delta$ is positive; and that α lies between $0°$ and $90°$ when $\tan\alpha$ is positive, and between $90°$ and $180°$ when $\tan\alpha$ is negative. For instruments of the equatorial type uncertainty can never arise, as the instruments can never be supposed to be directed so that their sight lines are nearly parallel to the common axis of the instruments (KP). For instruments of the theodolite type uncertainty can, however, arise at the determination of the quadrant of the azimuth, when observations are made near to the zenith; this will be considered later on.

The constant k, that is employed in the formulæ, will be determined by measuring the rectilinear coordinates of some well defined points in the photograph of an object on the earth, and then measuring the angular coordinates of the same points by means of the tube and circles of the instrument. For the same photographic plate $k\sin a'$ is also a constant, and thus Method III. is advantageous, if a great number of measurements are to be made on the same plate. Among the angles here employed, ϕ can be tabulated with x as an argument, as this angle is dependent only of x and the constant k.

If δ, α and β be calculated by means of the above formulæ, the following calculation will be performed by means of the formulæ given in the paper of Dr. Ekholm above mentioned.

7. I will now shortly give the formulæ that are applicable for instruments of the theodolite type.

In Fig. 6, let the great circle ZS represent the common vertical of the two instruments, from which the azimuth angles are supposed to be reckoned with watch-hands (sunwise). KC is supposed to be the optical axis of the instrument produced, ZC is the zenithal distance, z', read on the circle of the instrument, the spherical angle CZS the azimuth, say a'. The tangent plane in C corresponds to the photographic plate. The coordinate axes are supposed to be drawn in the tangent plane so that the axis of x touches the vertical circle in C, and the coordinates taken in the same direction, in which the corresponding spherical coordinates (z' and a') increase.

For the sake of perspicuity let in Fig. 7 the spherical triangle ZCF be separated from the rest. If we put

$$\Delta a = a-a'$$

and if the two auxiliary angles ϕ and ψ be introduced, defined as before, we obtain

$$\left.\begin{aligned} \sin z \sin \Delta a &= \sin \psi \\ \sin z \cos \Delta a &= \cos \psi \sin (z' + \phi) \\ \cos z &= \cos \psi \cos (z' + \phi) \end{aligned}\right\} \quad \ldots \quad \ldots \quad (13)$$

and the following systems of formulæ :—

I. Rectangular coordinates.

$$\tan \phi = \frac{x}{k}\,;\ \tan \Delta a = \frac{y \cos \phi}{k \sin (z' + \phi)}\,;\ \tan z = \frac{\tan (z' + \phi)}{\cos \Delta a} \quad \ldots \quad (14)$$

II. Polar coordinates.

$$\tan \phi = \frac{r \cos \Theta}{k}\,;\ \tan \Delta a = \frac{\tan \Theta \sin \phi}{\sin (z' + \phi)}\,;\ \tan z = \frac{\tan (z' + \phi)}{\cos \Delta a} \quad \ldots \quad (15)$$

Fig. 6.

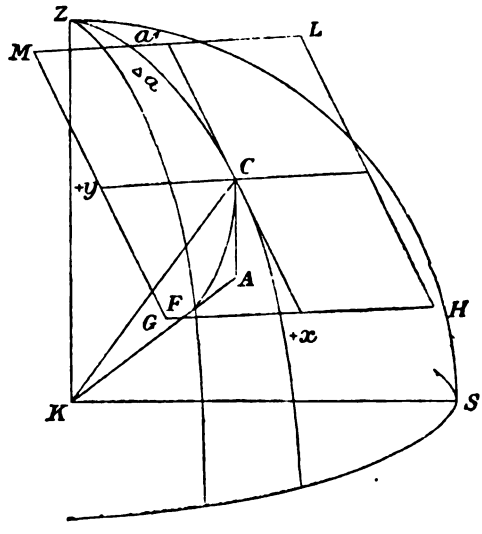
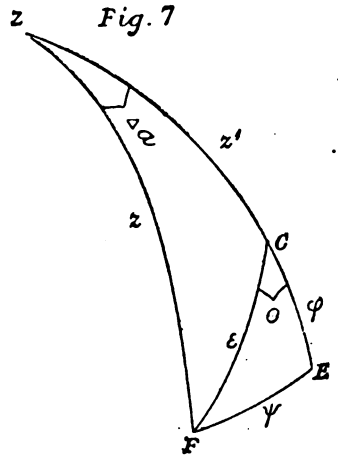


Fig. 7



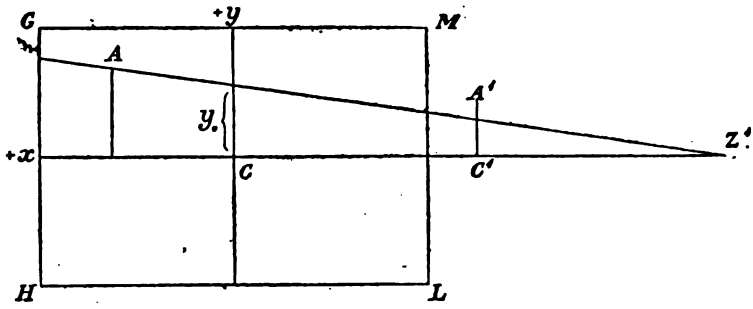
Here it must be observed that Θ ought to be reckoned from the positive x-axis, from the left to the right, in both instruments.

III. Measurement of x and y_o.

In Fig. 8 let the rectangle $GHLM$ be the photographic plate, laid in the plane of the paper. Z' is the projection on the photographic plate of the zenithal point Z. The straight lines, that are the images of the vertical circles on the sphere, all meet in Z', which, as the zenithal distance never is greater than 90°, always lies on the negative x-axis in a distance from C:

$$CZ' = k \tan z'$$

Fig. 8.



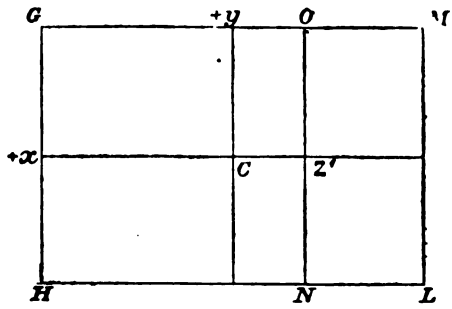
By laying a plane through the y-axis perpendicularly to the zenithal line KZ in Fig. 6 we obtain:

$$y_o = k \sin z' \tan \Delta a$$

Thus the formulæ in this case are:

$$\tan \Delta a = \frac{y_o}{k \sin z'}\,;\quad \tan \phi = \frac{x}{k}\,;\quad \tan z = \frac{\tan (z' + \phi)}{\cos \Delta a} \qquad \ldots \qquad (16)$$

Fig. 9



When observations are made near to the zenith, the quadrant of Δa is determined as follows. Because the angles ϕ and ψ can always be supposed numerically less than 90°, the first two formulæ (13) prove that $\sin \Delta a$ has the same sign as $\sin \psi$, and $\cos \Delta a$ the same sign as $\sin (z' + \phi)$. But according to the formula

$$y = \frac{k \tan \psi}{\cos \phi}$$

$\sin \psi$ has the same sign as y, and from Fig. 9, analogous to Fig. 8, we find,

that if the point A to be measured falls to the left of the line NO drawn through the image Z' of the zenith point parallel to the y-axis, $z'+\phi$ is positive, and if A falls on the right of NO, $z'+\phi$ is negative. Thus sin Δa has the same sign as y, and cos Δa the same sign as $x+k \tan z'$. Thus, if the point A falls within the rectangle GZ', Δa ought to be taken in the 1st quadrant,

if A within MZ', Δa in the 2nd quadrant
" LZ', " 3rd "
" HZ', " 4th "

Numerical Example.

$a' = 47° 30·'8$; $\delta' = +34° 56·'7$; $y = +32{,}5$ mm.; $x = +28{,}6$ mm.; $k = 125{,}8$ mm.

Method I. Formulæ (10)*

$\log x = 1·4564$ $\quad \log y = 1·5119$
$\log k = 2·0997$
$\log \tan \phi = 9·3567$
$\phi = +12° 48·'5$ $\quad \log \cos \phi = 9·9891$
$a' = 47\ 30·8$ $\quad$ Sum $= 1·5010$
$a' + \phi = 60\ 18·8$

$\log k = 2·0997$
$\log \tan (a' + \phi) = 0·2441$ $\quad \log \sin (a' + \phi) = 9·9389$
$\log \cos \Delta\delta = 9·9825$ $\quad$ Sum $= 2·0886$
$\log \tan a = 0·2616$ $\quad \log \tan \Delta\delta = 9·4624$
$a = 61° 18'0$ $\quad \Delta\delta = +16° 10·'8$
$\delta' = +34\ 56·7$
$\delta = +51\ 7·0$

Method II. $r = 43{,}29$ mm. $\quad \Theta = 48°39·'0$

Formulæ (11)

$\log r = 1·6364$
$\log \cos \Theta = 9·8200$ $\quad \log \tan \Theta = 0{,}0555$
Sum $= 1·4564$
$\log k = 2·0997$
$\log \tan \phi = 9·3567$
$\phi = +12°48·'5$ $\quad \log \sin \phi = 9·3458$
$a' = 47\ 30·8$ $\quad$ Sum $= 9·4018$
$a' + \phi = 60\ 18·8$ $\quad \log \sin (a' + \phi) = 9·9389$
$\log \tan \Delta\delta = 9·4624$

$\log \tan (a' + \phi) = 0·2441$ $\quad \Delta\delta = +16°10'·8$
$\log \cos \Delta\delta = 9·9825$ $\quad \delta' = +34\ 56·7$
$\log \tan a = 0·2616$ $\quad \delta = +51\ 7·0$
$a = 61°18'·0$

* If ϕ be tabulated, the 3 rows are excluded.

Method III. $y_o = +\ 26{,}9$ mm.

Formulæ (12) $\log y_o = 1{\cdot}4298\ \phi$ and a are calculated as shown in

$\log k \sin a' = \underline{1{\cdot}9674}$

$\log \tan \Delta\delta = 9{\cdot}4624$ the first vertical row in Method I.

$\Delta\delta = +\ 16^\circ\ 10'{\cdot}3$

$\delta' = +\ 34\ \ 56{\cdot}7$

$\delta = +\ 51\ \ 7{\cdot}0$

ADDITION TO THE ABOVE SOLUTION GIVEN BY DR. OLSSON.

BY NILS EKHOLM, Hon.Mem.R.Met.Soc.

A later consideration of Dr. Olsson's formulæ for the equatorial photogrammeter has suggested the following simplification of the formulæ (1) given in my last paper[1] combined with those of Dr. Olsson.

Let ϕ_1 and ψ_1 denote the auxiliary angles for the first equatorial, ϕ_2 and ψ_2 those for the second, and for the sake of shortness put $a' + \phi_1 = A$, $\beta' + \phi_2 = B$.

Then by the formula (6) of Dr. Olsson

$$\left.\begin{aligned} \sin a \sin \Delta\delta &= \sin \psi_1 \quad (1)\\ \sin a \cos \Delta\delta &= \cos \psi_1 \sin A \quad (2)\\ \cos a &= \cos \psi_1 \cos A \quad (3) \end{aligned}\right\} \text{I.}$$

$$\left.\begin{aligned} \sin \beta \sin \Delta\delta &= \sin \psi_2 \quad (1)\\ \sin \beta \cos \Delta\delta &= \cos \psi_2 \sin B \quad (2)\\ \cos \beta &= \cos \psi_2 \cos B \quad (3) \end{aligned}\right\} \text{II.}$$

$\Delta\delta = \delta - \delta'$ being the same for a corresponding point at the two instruments.

Multiplying I. (2) by II. (3) and I. (3) by II. (2) and dividing by $\cos \Delta\delta$ we get

$$\sin a \cos \beta = \frac{\cos \psi_1 \cos \psi_2}{\cos \Delta\delta} \sin A \cos B$$

$$\sin \beta \cos a = \frac{\cos \psi_1 \cos \psi_2}{\cos \Delta\delta} \sin B \cos A$$

and by addition

$$\sin (a + \beta) = \frac{\cos \psi_1 \cos \psi_2}{\cos \Delta\delta} \sin (A + B)$$

Also multiplying I (2) by II (2) and dividing by $\cos^2 \Delta\delta$,

$$\sin a \sin \beta = \frac{\cos \psi_1 \cos \psi_2}{\cos^2 \Delta\delta} \sin A \sin B$$

Introducing these values in our formulæ (1) cited above we obtain

$$\left.\begin{aligned} x &= \frac{b \sin B \cos A}{\sin (A+B)} = b - \frac{b \sin A \cos B}{\sin (A+B)}\\ y &= \frac{b \sin A \sin B}{\sin (A+B)} \cdot \frac{\sin \delta}{\cos \Delta\delta}\\ z &= \frac{b \sin A \sin B}{\sin (A+B)} \cdot \frac{\cos \delta}{\cos \Delta\delta} \end{aligned}\right\} \text{III.}$$

[1] *Quarterly Journal.* Vol. XIX. p. 42.

where

$$A = \alpha' + \phi_1,\ B = \beta' + \phi_2;$$

α' and β' are read on the circles of the equatorials and ϕ_1, ϕ_2, $\Delta\,\delta$ and δ are found as shown in Dr. Olsson's paper. Thus we need not calculate α and β.

There may be a slight difference between δ'_1 and δ'_2 and between δ_1 and δ_2 (notation analogous to that used in my cited paper, p. 43) due to instrumental errors; if such be the case, the arithmetic mean of δ_1 and δ_2 and of $\Delta\delta_1$ and $\Delta\delta_2$ must be introduced in the formulæ III.

Then the shortest distance Δ between the sight-lines will be

$$\Delta = \frac{2b}{\cos\frac{\Delta\delta}{2}} \sin\frac{\delta_1 - \delta_2}{2} \frac{\sin A \sin B}{\sin(A+B)} \quad \ldots \quad \ldots \quad \text{IV.}$$

The formulæ III as well as the formulæ (1) above cited combined with Dr. Olsson's formulæ are both very convenient for numerical work, so that a double calculation by means of the two systems will give an excellent control.

Similar simplifications are not applicable for the theodolite photogrammeters, as for them generally $\Delta\alpha$ is different for a corresponding point at the two instruments.

DISCUSSION.

Gen. R. STRACHEY, in a communication to the Secretary, said:—This paper may be regarded as being supplementary to that of Dr. Ekholm (*Quarterly Journal*, Vol. XIX. p. 38). It is designed to supply more exact formulæ for the calculation of the position of clouds obtained from photographic pictures, by the adoption of spherical coordinates instead of rectilinear; the discussion being made to embrace the cases both of cameras mounted as theodolites, and equatorially as proposed by Dr. Ekholm. Whether such refinements in computations of the heights and position of bodies so indefinite in their nature as clouds, are likely to be of practical value is perhaps questionable, and it would have been instructive to have had examples of actual observations treated with both in the approximate and more accurate manner for comparison. If, as is by no means improbable, the unavoidable uncertainties are much in excess of the differences brought out by the two methods of computation, the additional refinement seems uncalled for. The system last tried at Kew, by which the cameras were fixed with their optical axes directed to the zenith, may be regarded as a particular case of Dr. Ekholm's equatorial mounting. By it the direct comparison of the two sets of pictures got at the ends of the base, was made possible by simple superposition, and such a system might perhaps be extended so as to get directly comparable pictures from any point in the heavens, which would admit of almost all calculation being avoided, and the results being treated almost as simple "observations."

ON SOME PHENOMENA OF THE UPPER AIR.

An Address delivered to the Royal Meteorological Society, April 18th, 1894.

By RICHARD INWARDS, F.R.A.S.

President.

It must be confessed that the human family are not placed in the best position for entering upon the study of the upper air, for we are on the wrong side of the earth's envelope for this purpose, and our position has been compared to that of an oyster at the bottom of the English Channel, trying to form some notion of the play of the waves and currents above by observing the small eddies and tremors which find their way to the little nooks and corners which constitute his domain at the bottom of the sea.

We have indeed done a great deal towards accumulating accurate particulars of the state of the air in its lowest layers, but the great field of research above us is still but little known, and we have to guard against attaching too much importance to minute and multitudinous observations below, while we are but too apt to neglect the broader researches into the great aerial ocean which is ever flowing above our heads, and out of our immediate reach.

It is the dream and aspiration of every meteorologist to know something more of this ocean of air, and it must be in the domain of this higher meteorology that the further conquests of our science must be won.

There are three principal ways in which the higher atmosphere may be studied.

First, by going and living in it, somewhere on one of the great mountain chains which rise many miles into the air in various parts of the globe;

Second, by ascending into it by means of balloons; and

Third, by the study of the upper currents, as shown to our sight by the movements of the clouds.

I shall have a few words to say on each of these methods of observation, and I must ask the Fellows to forgive me for adopting a less technical style in these remarks than that to which they are accustomed within these walls. My reason is a sufficiently good one (next to that of my own shortcomings), and is, that the subject is so vast that I should have little chance of finishing in one short hour were I to give anything but a rapid and general glance at the subject.

If we imagine an observer provided with optical aids similar to our own, and viewing the earth, say from somewhere on the darkened part of our own moon, such a person would be able to take a much more comprehensive view of the movements of the air than we can ever obtain, for he would see masses of clouds wandering over oceans and continents, desert wastes, and polar

spaces, and, having the advantage of a comprehensive view of a hemisphere at once, he would not be long, at any rate with respect to the great cloud-bearing currents, in forming just notions of their movements.

The earth would be to him a splendid object about 16 times as large as the sun, and probably the brightest and most beautiful feature to him would be the ever shifting veil of clouds which he saw spread over its surface. In some of the densest, and to him brightest spots, we should, however, perhaps be suffering all the horrors of storm, thunder and wreck, small commotions which would be quite invisible from the point of view which we have just imagined.

One of the first questions to be asked, and one of the last to answer satisfactorily, is, How thick is the envelope of air which surrounds the earth? This is one of the things about which little consolation will be obtained by referring to meteorological works, for the various authors hover between 20 and 500 miles in their estimates of the height of the air.

But although we have no definite knowledge of where the atmosphere really ends, we are well acquainted with the sum total of its weight, and we know that at a height of about 3 miles half of its mass is below our feet. We are told, too, that the air cannot reach further into space than the point where the force of gravity is so diminished by distance as only just to equal the natural repulsive force with which the atoms of air (like those of all other gases) are striving to get away from each other. It is not too much to hope that experiment will some day enable us to fix this point.

Now the first way that I mentioned of extending human knowledge in an upward direction is by climbing a high mountain, and by living at a great height, to endeavour to study while actually in it some of the properties of the higher air. Dr. C. Theodore Williams, a few months since, gave us an interesting account of life in the higher altitudes of Colorado, and it has been my own lot to have lived on the great mountain chain of the Andes for about a year, and to have had opportunities of making notes which support the conclusions at which he arrived.

In these high plains of the Andes we get a good opportunity of studying the effects of rarefied air on animal life, and one of the first things we should expect in people who have to live in an atmosphere which only allows them to take in about two-thirds of the usual quantity of oxygen each time they breathe, would be that they would be sure to suffer from lung troubles, and that strangers coming from lower levels, where they had been accustomed to a full supply of that prime necessary of life, would fall ill or pine and die. Our surmises, though apparently founded upon reason, would be woefully wrong, for we should find ourselves among a people to whom lung diseases are almost unknown, who have no words in their language for consumption or catarrh, and who go about their daily occupations without ever suspecting that they are badly used in being deprived of so large a portion of their atmosphere. As to the stranger who arrives among them, after the first inconvenience caused by the sudden change, he generally improves in health, and if he had any chest disease when he came, he generally promptly loses it.

Another thing which does not seem unreasonable is that birds, having but little more than half the density of air to beat against with their wings, would be unable to fly so swiftly or so far as those in lower air, but yet here we see the great Condor spreading his wings without an effort and sailing over the highest mountain peaks, while at 10,000 ft. altitude the little humming birds flit about hour after hour without even seeming to wish to settle.

I believe the eggs of birds are, at these heights, provided with a larger air bubble.

We find the men (I speak of the Aymará Indians, among whom I lived) to be a large chested and rather short legged race, with a great capacity for prolonged and patient exertion, but with no particular aptitude for great or sudden efforts.

One of the first things we notice here is that boiling water is not so hot, and certain kinds of food cannot be cooked at all by boiling. The sky is of a darker and purer blue. Sounds are not so loud, nor echoes so clear or frequently repeated as those below. Pumps and siphons do not raise water to the same height, fires will not give out so much heat, and furnaces which will melt certain minerals at ordinary altitudes will not do so here.

Exertion soon becomes fatiguing, and only a few yards running will cause a stranger to pant for breath.

The clouds are often seen widely spread out beneath your feet, and, just as in some of the pictures I hope to exhibit, one seems to look around on a wide sea of clouds, studded with blue islands, where the mountain tops pierce through into the sunshine, while the cloud-sea fills up the valleys, following every hollow and winding along every torrent bed, and showing bays and creeks without number, just as on the shore of a veritable sea or lake beneath.

In the high plains which we cross at night the electric effects are most startling, and I well remember my surprise at seeing brushes of flame issuing from the mules' ears while the arriero's spurs seemed like two fiery stars dancing near the ground. Every time we touched the manes of the animals a line of fire followed the hand, and a hissing noise was heard. These things are not rare, and I am prepared to believe that in Canada there are times when, as stated, an ordinary gas jet can be lighted by a natural spark from one's finger.

Then on these great mountain plains we often see whirling columns of sand (in form and motion like waterspouts at sea) careering along the vast dusty desert, and although one can sometimes see as many as six of these at once, yet it seems a rare thing to be actually enveloped in one. Their horizontal motion over the ground is quite leisurely, though there is a furious current of air and sand curling round in their centres.

The importance of high stations for weather observatories is fully recognised by other nations; and I need only name the gallant effort of Harvard College, who have, at their own expense, established in Peru an Observatory with full equipment of recording instruments on Mount Charchani at a height of 16,650 feet above the sea. When I tell you that this

Observatory is more than 3,000 miles from the College, and is also in another country and hemisphere, some notion may be had of the effort necessary to establish and maintain it.

The second method of attacking the regions of the higher air is by means of balloons; and since Montgolfier first proposed to introduce French soldiers into Gibraltar by means of his balloon, there have been many ascents into the atmosphere by these means. Though the inventors did not at first venture themselves into the car of the balloon, yet Montgolfier proved the practicability of his scheme by sending up sheep and fowls, which duly came down alive.

It would be a task far too long to enumerate all the air voyages which have enriched science by the discoveries of new facts as to heat and moisture, wind and tempest, but in 1850 Messrs. Barral and Bixio found at 20,000 feet the temperature had sunk to 15° F. This was in a cloud, and on emerging from this 3,000 feet higher, the temperature sunk as low as −38° or 70° below freezing point. These voyagers, too, had the honour to be the first to pass through a cloud made up entirely of fine needles of ice, so that they managed to experience an arctic temperature in less than an hour's journey from Paris.

Then there were the memorable ascents made by our countryman Mr. Green, who was accompanied by Mr. Welsh, F.R.S., of the Kew Observatory (whose portrait on an old daguerrotype, and with a group of other celebrities, will be found in the Exhibition), and they confirmed previous observations as to the air becoming about 1° colder for every 300 feet rise. Mr. Green, too, was one of the first to witness two complete sunsets on the same day; for though he started from the earth some time after sunset, he rose so rapidly into the air that he soon saw the sun again, and watched it once more setting behind a more elevated horizon.

Then Mr. Creswick, of the Greenwich Observatory, made an ascent in a very old and damaged balloon, and after many perils came down, luckily, without accident.

But after these came the never to be forgotten series of ascents by our own Mr. James Glaisher, F.R.S., a former President of this Society, and a man still hale, though long past 80, who, with Mr. Henry Coxwell the aeronaut, also still living, undertook for the British Association a series of ascents provided with all the scientific apparatus necessary for a thorough examination of the currents of air through which they were to pass. They made 28 ascents, principally in a balloon made of American cloth, and not of silk, as the custom had been.

In the very first ascent some interesting facts were noted. At 15,500 feet the temperature had ranged between 26° and 31°, but after getting as high as 19,500 feet it was found to be 11° warmer, and just as they were taking off some of their thick clothing, they suddenly encountered a cold current of the temperature of 16°, all in a few moments. They came down with enormous rapidity, at the rate of about 4,000 feet in a minute, and they also sunk through a cloud 8,000 feet in thickness.

In 1862 they made the ascent in which they reached an altitude never before attained and which has not since been surpassed, and they ran very great risk of perishing from the drowsy faintness produced by breathing the rarefied air. Mr. Glaisher collapsed, and although his brain retained for some time its thinking and observing powers, yet he found himself unable to move a single muscle and finally he fainted; while in the meantime Mr. Coxwell, whose hands were frost-bitten, only just managed to open the gas valve with the aid of his teeth, so as to enable them to descend from their seven miles altitude and to land safely on the earth. I can remember in these rooms hearing Mr. Glaisher's graphic description of his sensations when in a fainting condition, and his being "heckled" by a medical objector who seemed to see some difficulty in his account of the symptoms.

Mr. Glaisher has described in his *Travels in the Air* all the moving incidents in subsequent ascents, the grand cloud scenery passed through, the warm and cold currents, the layers of clouds at different heights, some of them raining freely into each other, the various effects of the rarefied air on themselves and on the pigeons they let loose from time to time, and he relates even so small a circumstance as the cork flying out of a water bottle owing to the expansion of the air within.

But there is a mode of getting information from balloons without undergoing the danger, and this is by sending up, instead of an observer, a series of instruments so cunningly contrived as to register the various changes of condition through which the balloon rises. This has just been done in France through the enterprise of M. Hermite, and the results are most interesting, for it appears that one of these balloons has surpassed all previous ascents, and has risen to a height of ten miles into the air and brought down automatic records of its journey. Mr. Green long ago expressed the opinion that it was useless to hope to ascend higher than ten miles even in a balloon inflated with pure hydrogen gas, but he probably reckoned on a living observer being carried up.

This French balloon rose to a point where the pressure was only 4·1 inches and the temperature −104 F. It seems from the results of this ascent that the temperature of the air decreases pretty regularly above 12,000 feet at the rate of 1° for every 330 feet rise into the air.

A word about the possibilities of the human animal taking to himself wings and flying into the space above. It may be said that a great many inventors have occupied themselves with the problem, and that it is only recently that they have been rewarded by the least glimmer of hope.

In the 15th century that wonderful Milanese who seemed to have combined within himself the powers of a host of masters,—I mean Leonardo da Vinci,—made many designs for flying machines, but in describing one of the most ingenious of them he let fall an observation which shows that he had not much faith in their success, for he writes to a pupil who was going to try the flight: "Thou wilt experiment with this instrument over a lake, and with a long leather bottle round thy waist, so that thou drownest not." Here we have an instance of an experimenter anticipating failure in what he

attempts, but inventing a most useful thing (the life belt) as an accessory to the abortive scheme.

Herr Lilienthal has, however, actually made a flying apparatus with wings of 15 square metres, and he has succeeded at Steglitz, near Berlin, in flying, or rather gliding, through the air for a distance of 278 yards, always, however, slightly declining towards the earth, at an angle of from 10° to 15°. (See *Nature*, December 14th, 1893.)

In order to start, he has to run smartly a few steps against the wind, an evolution which the larger birds of prey have to perform when they rise from level ground. And we are told the same thing of our British bustard, now becoming so rare.

But as to this possibility of flight, although science cannot look to it for much aid, yet since the appearance of Professor Langley's *Experiments in Aerodynamics* the subject has entered another phase, and this truly eminent investigator gives it as his deliberate opinion that "mechanical sustentation of heavy bodies in the air combined with very great speeds is not only possible, but within the reach of mechanical means we actually possess, and that while these researches are not meant to demonstrate the art of guiding such heavy bodies in flight, they do show that we have now the power to sustain and propel them."

We now come to the third method of getting knowledge about what is going on above us, and this we can do by studying the behaviour of the clouds which float over our heads.

Aristotle defined a cloud as a mass of vapour floating in the air, and if we substitute water for vapour, or call it visible vapour, or as Tyndall named it "water dust," we shall not have much altered the twenty century old definition.

Clouds are simply a form of water made visible by the cooling of the air which previously held the water in the form of invisible vapour.

Every cloud may be regarded as the top of an invisible warm column or current thrusting its way into a colder body of air, and one point should not be lost sight of, that the clouds themselves sometimes form a barrier to the horizontal motion of the currents that produce them, and it is common in thunderstorms to see an enormous mass of cloud climbing higher and higher into the air till it seems to topple backwards upon itself like the cap of foam upon a gigantic wave.

It is of the greatest importance that meteorologists should agree on the names by which the various clouds should be known, and there is, I believe, an international scientific committee engaged in settling this point, and until we have their recommendations we can only go on using the names given them in 1803 by Luke Howard, an English Quaker gentleman, whose portrait you will see in the Exhibition, and who in his daily business walks studied well the sky, until he was able to frame a list of names for the clouds, by which names they have since been known all over the world.

But Mr. Symons, who is always unearthing some treasure, has called my attention to the work about the same time of Lamarck, who published in his *Annuaire Météorologique* a very careful system of cloud names,

As early as the year 10 (not of our era, but of that of the first French Republic) he gave us a classified list of clouds. In the *Annuaire* for 1802 he divides clouds into :—

Nouages en voile. The veil cloud, which answers to our haze or mist.

Nouages attroupés. The gathered up or assembled clouds, which correspond generally to our cumulus and strato-cumulus.

His next class was that of *Nouages pommelés*, or dappled clouds, which are now known as cumulus.

He then describes *Nouages en balayures*, the swept cloud, which he compares to the marking left in dust by the action of a broom. This is clearly our mare's tail or cirrus cloud.

Then come *Nouages groupés*, or our cumulo-nimbus, the true thunder-cloud, which from a flattish base rises to a great height in the air with the upper borders always clearly cut against the sky, and described by him as rounded, lobed, mammellated, and festooned. He further makes the observation that the most rounded and clearly cut edges are always on the side towards the sun. He puts this down as a rule without any exception, and ascribes it to the impulses given by the sun's light to the vesicles of water forming the cloud, on the shady side of which, he says, one may see torn edges and fissures which contrast with the close texture and sharp margin of the sunny side.

He promised to embody all this in a book to be called *Théorie de l'Atmosphère*, but I do not know if he ever did so.

In the year 18 (of the French Republic) Lamarck had amplified his list to twelve classes of clouds, and his names may be freely translated as misty, bordered, veil-like, frame-like, inflated, barred, swept, dappled, gathered, racing, grouped, and thunder clouds.

Each of these classes he splits up into from three to six varieties, for instance, the barred cloud he divides into confluent, isolated, obscure, undulating, and partially dappled clouds, showing he was a careful observer of the cirrus group. In all, he describes 31 different varieties under separate names. He then describes 8 kinds of fine weather skies, 6 of medium, and 12 of bad weather. The whole treatise is interesting and well worthy of translation into English.

In 1808 the *Annuaire* had begun to count the years in the usual way, and had dropped the names of the months Nivôse, Pluvieuse, &c. for plain January and February, but had adopted what he called "meteorological" months as well as the usual ones.

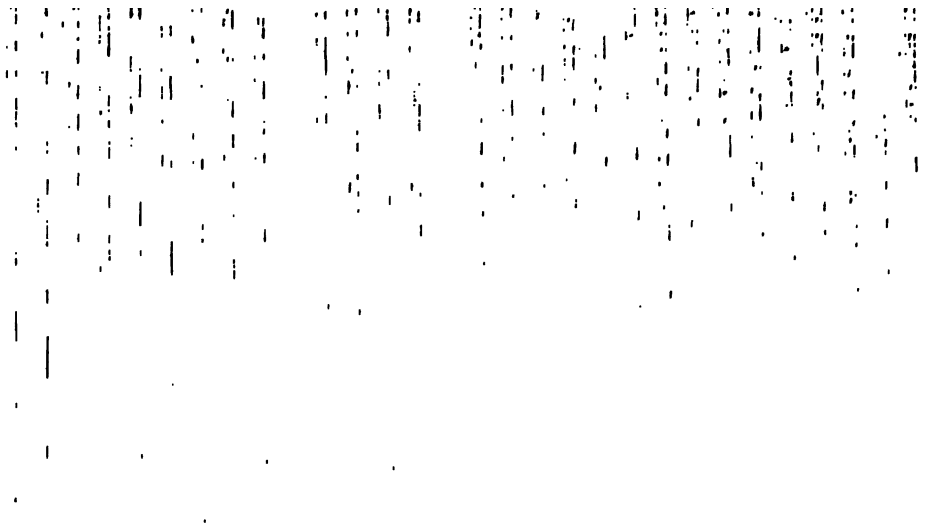
The names given to the clouds by our own Luke Howard are, however, those most in use not only in England but in other countries.[1]

He called the lower clouds—almost resting on the earth,—*Stratus*, which we may for popular purposes call the sheet cloud.

Then came *Nimbus*, which is a rain cloud, then *Cumulus*, which is the heaped up accumulated, or wool-pack-shaped cloud of our summer skies.

Lastly the *Cirrus*, popularly known as the mare's tail cloud of every day talk.

[1] Howard's Classic Treatise has been recently reprinted in English by Dr. Hellmann. A. Asher & Co. Berlin, 1894.



and at 6 miles distance appears a very different object. The small spotted, and minutely subdivided, shadowless cirrus cloud is always high. Large cloak-like clouds belong to middle air. I am not taking the torn portions of the lower clouds, or the wrack, as it is called, into account, though these may be called small clouds also, but they are easily known by their rapid movements.

Another guide to the height is the apparent *movement* of the cloud; and as a general rule the quicker a cloud seems to move across the sky the lower it is. This is in accordance with the well-known sight seen from the window of a fast train rushing through a park-like country, where the nearer trees seem to gallop past at a furious rate, while the distant ones scarcely seem to move, or by contrast appear to be going in an opposite direction. As a matter of fact the upper clouds nearly always move much faster than the lower, and the speed of the upper air may often be very correctly estimated by watching the march of the cloud shadows over a tolerably level country. On February 2nd of this year (Candlemas Day), for instance, I noticed the cloud shadows coursing over Hampstead Heath at the rate of 48 miles per hour, just about double the speed of the wind on the surface of the earth.

The shape of the clouds, with their fronts well raised, like crests, showed, too, that the higher currents were moving still faster, and it must be remembered that the cloud cannot move so fast as the wind which drives it. As this observation of cloud shadows was made on Candlemas Day, when the sun shone brightly, it enables me to give another blow to an old superstition; for according to all weather wisdom, we should have had a second winter after that had happened. You all know how signally in this year the adage has failed. Old Candlemas or St. Valentine's Day was also sunny this year.

The fifth point of attack in estimating the height of some clouds is their perspective effect. I may say that this observation applies more particularly to one form of cumulus cloud, which is often seen rolling up in successive waves or bars, and which has given it the name of *Roll Cumulus*.

These are shown in the photograph by Mr. Davies, which I shall put before you; but first I must ask you to consider a diagram showing the difference in the perspective effect of the wave-like clouds according as they are higher or lower in the air.

Let the eye on Figs. 1 and 2 be that of a spectator looking at the sky through a plate of glass *B C*, and endeavouring to mark on the glass the places where he sees each wave of cloud. If the clouds are equidistant and low he will get the marks in the position shown in Fig. 1, *A*, where there is a *rapid* falling off in the spaces between the lines.

In the second case, where the clouds are high, he will get his marks on the glass plate more equidistant, as shown in Fig. 2, *A*.

So that it may be said of waves of cloud as of those of water, that the nearer the point of view is to their level the larger do the nearer spaces appear in comparison to the distant ones.

I show you actual photographs of these two characters of clouds, and I

will have one of them inverted in the lantern for the purpose of showing how near is the resemblance between the waves of water and those of air, for if it were not for the ship upside down, you might easily take the appearance of these clouds for breakers rolling in upon the shore.

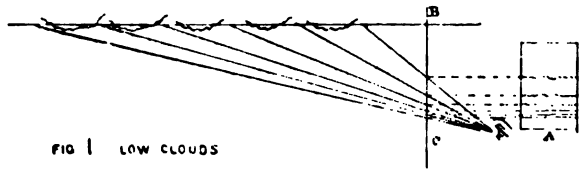


FIG 1 LOW CLOUDS

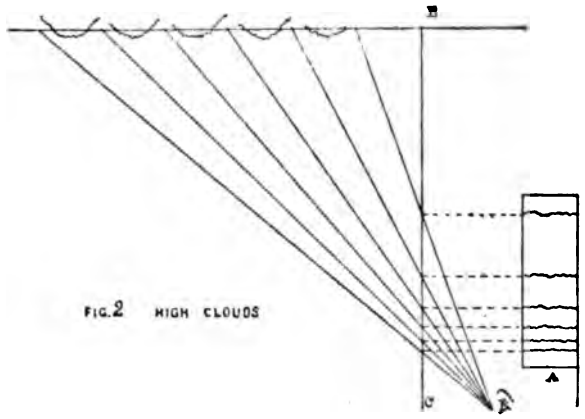
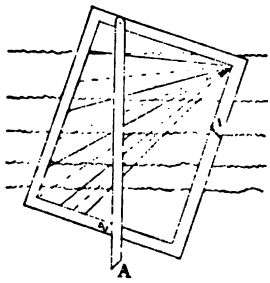


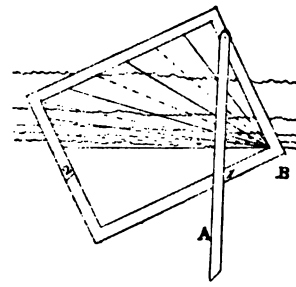
FIG. 2 HIGH CLOUDS

I have made a little instrument to aid in this mode of estimating the altitude of clouds; it consists of an oblong frame with wires radiating from one corner, and with a bar, *A*, pivoted on the frame so as to cross the radiating wires at any angle. (Fig. 3.)



HIGH CLOUDS (2 miles)

FIG 3



LOW CLOUDS (1 mile)

The instrument is so held between the eye and the clouds that the bar *A* seems to cut the wires in the same proportion as it does the horizontal cloud lines seen beyond. The bar *A* is always to be vertical. The position of *A* upon the frame indicates the height of the cloud series above the earth, which height would be infinite if the bar were parallel with the top of the frame and infinitely low when the bar is at right angles to the first position, and where the observer would be actually in the cloud.

Of course it would apply to any equidistant bodies, such as trees or houses seen through it, and would give approximately the spectator's position with respect to them. I may say that every alternate wire or every alternate cloud may be taken if more convenient. It is also obvious that the same series of clouds seen from the earth, and again seen from the top of a very high tower, would require different positions of the bar to correspond with the effects seen from these different points of view.

The sixth way of forming a judgment of the cloud heights is also of limited application, but is of much greater accuracy, and it consists of observing for how long a time the cloud remains directly illuminated after sunset. In other words, how long a time elapses between sunset on the earth and sunset on the cloud. I must again ask you to look at a diagram (Fig. 4), only promising you that I will show you afterwards some of Nature's own work in the way of cloud pictures.

Let the circle be the earth supposed to be seen from a point above the North Pole. The arrow shows the way the earth is turning round from west to east at the rate of 15° per hour.

S is the direction of the sun, which is of course just setting at *A*. When the earth has turned through 15°, so as to bring *A* to *D*, then a cloud would have to be as high as *C* to catch the sun's rays.

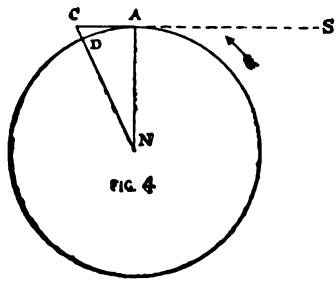


FIG. 4

I have exaggerated the angle to make the principle clearer.

A N is the earth's radius, say 4,000 miles in round numbers, and *C D*, the height sought, is found to be the difference between what is called the secant of the angle (15° in this case) and the earth's radius multiplied by the said secant.

This is all plain sailing for the mathematician, as he has tables of these secants for every possible angle. In the case I have imagined the spectator is supposed to be on the equator, the sun's declination is zero, and the cloud is in the zenith, but it may be anywhere on a meridian. For other latitudes and seasons the case is more complicated, but I may say that under the conditions named, if a cloud caught the sun's rays 1 hour after sunset it would have to be 140 miles from the earth's surface, while if it could be conceived to be visible so long as 4 hours (during which the earth would have turned through an angle of 60°, the cloud or object would have to be 4,000 miles removed from the surface, because the secant of 60° is just double the radius. I found after working out this method that it had been previously applied by our esteemed Fellow, Prof. Archibald, in calculating the height of the zone of volcanic dust with which the volcano Krakatoa encircled the earth in 1883. Prof. Archibald, in the Report to the Royal Society, gives the whole formula, and I find that an American observer at Potosi has also used it in estimating the height of a particular group of clouds, and which he found to be 10 miles above the surface of the earth.

I commend this to our merchant captains, who may find themselves becalmed in the doldrums, as they will there be under very favourable conditions for making the observations, which are very simple, and can be worked out at leisure; for the place of the ship, the date, and the moment of the disappearance of the sun's light from the cloud, are all the particulars necessary to note at the time. Full tables may perhaps be forthcoming to assist in this calculation.

Mr. Wingfield, an Australian observer, has proposed to estimate the cloud heights from the position of their shadows; but this method, though ingenious, is, I am afraid, impracticable on account of the difficulty of identifying at a distance the shadow of any particular cloud, also that the thickness of the cloud causes its distant shadow to be very different in proportions from the observer's view of the cloud itself.

Now all these methods come under the description of rough and ready rules; but the plan of taking the altitudes of clouds by the usual processes of trigonometrical surveying ought to be considered, but I can do no more than mention the general scheme, and give an illustration of perhaps the simplest possible case.

It is well known that if two angles and a side of any triangle are known, all the other measures of the triangle can be calculated, and it follows that if from the ends of an accurately measured base line on the ground two observers take simultaneously the angle which a line to the cloud forms with the base, then it is only a matter of calculation to compute the cloud's height.

If there should be one person present to whom this is not clear, I will put a more simple case, which might occur in estimating the height of a balloon (I take this because it is a more definite object than a cloud, but the principle is the same).

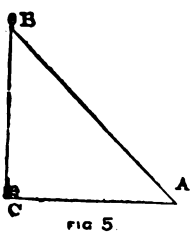


FIG 5

Let *B* (Fig. 5) be a balloon, which at a given time is vertically over some object, such as a church spire, *C*, and an observer at *A* is noting at the same time that a line to the balloon makes an angle of 45° (or half a right angle) with the ground. *A B C* then is half of a square divided diagonally, and therefore, as all the sides of a square are equal, *B C*, the balloon's height, is equal to the distance *A C* measured on the ground or on a map.

The merest guess at the height of a cloud from which rain is falling may be given by taking note of the size and speed of rain drops, and it is a common observation (how true I do not know) that when rain drops fall into water and throw up bubbles, the rain is likely to last a long time.

The cloud velocities at high altitudes have been carefully noted at the Blue Hill Observatory, near Boston, U.S., and show practically that at about 5 miles height the movement is three times as fast in summer and six times in winter, as compared with the currents on the earth's surface. In a new work by Prof. W. M. Davis, called *Elementary Meteorology*, there are many interesting facts about the speed of the wind at various altitudes. The rule seems to be that the higher the level the faster the movement, but there

must, of course, be a level of maximum speed, though the position of this is not yet ascertained exactly.

I show you some pictures of stratus clouds, which must be regarded as the infant form of cloud hovering near its parent earth or sea. Sometimes it may be watched on a fine evening in summer melting away into the air like ice in water. The rate of disappearance is almost incredibly rapid, whole acres vanishing in a minute of time. In these cases the edges become smoother, and the fish-like shape of the cloud becomes apparent, and generally the rounded side is below and the flattest above.

As to the cumulus, or what may be called the adult form of cloud, I have already mentioned something about it in speaking of cloud heights, but the photographs, of which there are a great many, and generally very beautiful examples, will show you more than any verbal description.

There is one picture of what at first sight seems a cumulus cloud nestling under the falls of Niagara, but this is really a mass of ice constantly augmented by the freezing of the spray from the cataract. It is a fossil cloud, as it were, showing the lines and contours of its prototypes, which are floating in the air. It will be observed that this frozen cumulus grows by additions to its upper side.

Now the cirrus clouds, of which it is more difficult to give you any perfect examples on account of the difficulty of photographing them, may be considered as clouds in old age, and which have passed through the previous infantile and adult conditions I have already named. They are to all appearance moving much more slowly than other clouds, but this is only a deception which arises from their distance from the observer, they really move faster than the lower clouds. It is almost proved that they consist entirely of fine crystals of ice, because of the great cold at their altitude, which would not allow of the existence of vapour there. Then their effects in causing halos correspond with the known optical properties of ice, and in addition to these considerations, aeronauts have several times, when at great heights in the air, passed into cloudy masses of fine spicular ice.

Though cirrus clouds are generally relics and vestiges of other clouds, yet on their descent they have been observed to become centres of condensation and have again grown into the lower forms of cloud, and it is reasonable to suppose that the fine rain into which they would dissolve may sometimes be converted again into cloud before it has time to reach the earth. They seem, according to the Hon. Ralph Abercromby, to be found in all parts of the world, and it is, therefore, to be expected that those seen in the tropics are at a greater height than their polar cousins, also that they are more apt to form in cold nights after hot days, but as they are mostly invisible at night one cannot be certain if this is the case. It has not been my fortune to see cirrus clouds changing into any of the lower forms, but I have at sunset seen murky patches of lower clouds arrested under them and evidently ready to coalesce.

Cirrus clouds and their cirro-cumulus (mackerel sky) neighbours may occupy several layers of the atmosphere and move in different directions at

various heights, and I exhibit to you a photograph of several strata of clouds one above another. Sometimes ice or snow particles will drop from the uppermost and pass through the whole series, getting successive coatings of ice varnish as they pass downward until they arrive on the earth in the form of enormous hailstones, the photographs of some of which I show you. This is without supposing the hail stones to make loops in their course and rise again into the clouds even more than once, a thing we know to be possible, from the effects of tornados which sometimes carry still heavier objects into the air. But all this is carefully gone into by the Hon. Rollo Russell in his excellent monograph *On Hail*. The same author has given us some valuable rules respecting cirrus clouds, and I only regret that he has not secured photographs of some of the quaint forms he so well decribes.

He has mentioned auroral cirrus, filmy cirrus, sheet or pallio cirrus, tufted or shower cirrus, fish bone or vertebrate cirrus, as well as radial, curdled, barred, and ribbed cirrus, but he does not propose these as names for adoption but only adjectives chosen by himself, for purposes of description.

The Rev. W. Clement Ley has also given new names to many varieties of the cirrus clouds, but we hope to some day see all his results in his great work on the subject. Mr. Gaster is also studying this subject.

With regard to some other matters concerning the higher air, one cannot avoid a few words of reference to what are known as the auroræ borealis or australis, literally the northern or southern dawns, as they were named by Gassendi, who acted as their godfather. They are sometimes seen in these latitudes, but never in the degree of splendour with which they paint the skies of polar regions. Professor Lemström, of Helsingfors, has given to the world, in his truly noble book on the subject, all that is certainly known of the phenomena, and he has added to his description a great many very striking drawings, two of which I can show you; but they are seen at once when magnified on the screen to want the finish and perfection of photographs. Professor Lemström not only studied the auroræ in the sky, but he actually produced a similar effect by an arrangement of rods and wires which sent long beams of naturally produced electricity into the air, closely imitating the real phenomena in kind if not in magnitude. Columns of light ascended from his apparatus more than 100 yards into the air.

The auroral displays of greatest brilliance occur at intervals more or less regular, corresponding with the periods of greatest magnetic disturbance, which in their turn appear in sympathy with the greatest number of spots which are seen upon the sun.

The height of the auroral display above the earth is found by Dr. Paulsen to range between 61 metres and about 67 kilometres, or, say, 41 miles, well within the limits of the atmosphere, though apparently the fiery trains never seem to reach the surface of the earth, and they have been observed lower in elevation the further north they have been met with.

Some of the auroral drawings give the notion of hosts of spear-armed warriors, and remind one of the passage in Julius Cæsar, where Calphurnia says she has seen—

"Fierce fiery warriors fight upon the clouds
"In ranks and squadrons and right form of war," or again in the same play, when
"Exhalations whizzing in the air" are mentioned.

With the researches of Prof. Dewar before us on the liquefaction of the air, we can scarcely refrain from speculating as to what would be the electric effect if the upper air in Polar regions should actually liquefy and descend in a sort of cascade to be reconverted into air before it reached the earth. We are told that the cold measured on the surface sometimes descends in high latitudes to as low as $-60°$ Centigrade, and it is not difficult to imagine that a few miles from the surface the temperature might sink another 120°, and that we should so obtain the conditions for converting the higher zones of air into a liquid. In a recent auroral display several observers remarked transverse patches like cirrus clouds crossing the general lines of the discharge.

Although not strictly a phenomenon of the upper air, I have the pleasure to show you a picture of a rainbow as photographed successfully by Col. Saunders, of Cheltenham. It will be seen that the space inside the bow is much more brightly illuminated than that outside, and the same thing is shown in a photograph by the Rev. F. C. Lambert, which you will see upon the walls. Regarding rainbows I may say that, under favourable conditions, they may be sometimes seen very near to noon, and I have seen one in Spain as late as 11.30 a.m. For this you require a mountain background to the north, and you may then get a low outer bow shown against the grey hills behind. This is, no doubt, (as Mr. C. L. Prince has pointed out) the rainbow at midday alluded to by Seneca, and which expression has been erroneously translated as a rainbow in the south.

There is also a photograph showing the corona round the sun, and Mr. A. Stroh is to be congratulated in having so well succeeded in depicting this beautiful effect.

For all these photographic illustrations we are grateful to those who have so successfully overcome the difficulties and have favoured us by lending their hard-won results.

To Professor Riggenbach, Mr. Cohen, Mr. Clayden, Mr. Davis, Mr. Stroh, Mr. Birt Acres, Mr Charters White, Col. Saunders, Admiral Maclear, Mr. Hussey, Mr. Hall, and to the Sciopticon Company we give our very best thanks.

I have to conclude by making a practical suggestion, and to urge the desirability of establishing somewhere in these islands a good cloud observatory. The times are ripe for such an institution, which need not be for a permanence, but which could do a great deal towards fixing our knowledge of the clouds and upper air currents, say in 10 years, or in even half that period.

The photographic facilities are now complete, the difficulties have practically vanished, and we have lenses which will command a quarter of the visible sky, we have plates which are specially sensitive to the red rays of the spectrum, and screens or mirrors which will filter off the too active blue-violet rays, and depict the most delicate markings even against a bright sky.

Pictures may be taken in the most rapid succession by merely touching a trigger, and results can be printed as permanently as any document, legal or otherwise, which emanates from the press. We only want a suitable tower giving us a free horizon, and the benefactor to bear the expense.

The modest funds at the disposal of this Society would not enable us, unassisted, to undertake the inquiry, and one can only hope for some liberal augmentation to our research fund, founded by Dr. Williams, my predecessor, to help us on in this or other directions. Other nations are doing so much that England ought not to be behind.

This Society is not so much concerned with the bare utility of Meteorology as with making large additions to human knowledge in a skyward direction. We are encouraged in our pursuit, however, by the results which sometimes happen, even in a commercial sense, and M. de Parville, a French author, has estimated the saving to British navigation alone as 10 millions sterling per year resulting from the better knowledge of the course of winds and currents, which first became available after the publication of Maury's famous charts. It used, he says, to take 250 days to sail to Sydney and back from this country, and it can now be done in half the time.

Just as the Greek or Egyptian geometer, who first busied himself with the various properties of conic sections, could never have dreamed that long ages afterwards mirrors would have been constructed on his rules, which from lighthouses on every coast would flash a warning light over the ocean and be a boon and a blessing to the navigators of all future time—so in some measure is it with the study of the air, we go on feeling its pulses, examining its properties, and analysing its constitution, not merely with the hope of being able to reduce what seem to be its whims and caprices to an orderly sequence, and so to bind it to the service of man, but with the satisfaction which all civilised beings must feel in extending human inquiries further and further beyond the bounds of the known, into the vaster regions of the yet unlearnt.

LUKE HOWARD, F.R.S.

(Frontispiece.)

As the subject selected for this year's Exhibition of the Royal Meteorological Society was "Clouds: their Representation and Measurement," it has been thought desirable that a portrait of Luke Howard, F.R.S.—who may almost be termed the father of English meteorology, and who was the author of Howard's cloud nomenclature—should be given in the *Quarterly Journal* along with the Catalogue of the Exhibition.

The portrait in the Frontispiece has been taken from a crayon drawing made by Bedford about 1848, and now in the possession of Mr. W. Dillworth Howard, F.R.Met.Soc.

The following biographical notice has been taken from the *Proceedings of the Royal Society*, Vol. XIV.:—

LUKE HOWARD was born in London in 1772, a date which carries us back to the early years of the reign of George III., and opens a long vista of history in which great political changes are rivalled by the grandest discoveries of modern science.

Luke Howard's parents, members of the Society of Friends, sent their son to a country school in North Oxfordshire, where, as he was accustomed to say in after life, "he learnt too much of Latin grammar and too little of anything else." But having even then an observing eye, he began to notice the appearances of the sky and forms of clouds; and his inclination towards meteorology appears to have been fixed by his impressions of the remarkable atmospheric and meteoric phenomena which, as those acquainted with the history of meteorology will remember, characterised the year 1783.

From school young Howard went as apprentice to a chemist at Stockport, which was then a quiet country town. In this situation he devoted his spare hours to the course of self-improvement which he had already begun, and acquired that knowledge of French, botany, and the principles of chemistry which was so useful to him in after years. The quickening effect produced on his mind by the works of Lavoisier he described as "like sunrise after morning moonlight," an effect which has been felt by many a student.

In 1798 he entered into partnership with William Allen, whose reputation as a manufacturing chemist has long been recognised. This connection, however, was brought to an amicable close a few years later, and Howard, taking as his portion the laboratory at Plaistow, applied himself to the business therewith connected, and to his favourite scientific pursuits. Making use of his observations of natural phenomena, he wrote a paper *On the Modifications of Clouds*, and read it at a meeting of the Askesian Society, of which he and his friend Allen were members. This paper, as he himself tells us, "the result of his early boyish musings, enriched by the observations of many a walk or ride, morning and evening, to or from his day's work at the labora-

tory," was published in 1803, and made known the author's name and ability to a wider circle. The Askesian was not a publishing Society; otherwise Luke Howard might have been better known than he is as a pioneer in departments of science besides meteorology. "I know," writes one of his friends, "that one or more of his papers related to atmospheric electricity, and another was an anticipation of the cell theory, as regards the structure and functions of plants, founded on microscopic investigations."

Many, if not all, the articles on meteorology in Rees's *Cyclopædia* were written by Luke Howard. He contributed a series of papers to the *Athenæum* embodying the results of his meteorological observations from the year 1806; and these he published in two volumes (1818-20), under the title *Climate of London deduced from Meteorological Observations made in the neighbourhood.* This, republished in 1833, in three volumes, has become one of our standard works on meteorology.

Luke Howard was elected a Fellow of the Royal Society in 1821. From that time his reputation as a meteorologist increased, and eminent persons in many parts of the world opened a correspondence with him, which, in some instances, became the initiation of a lasting friendship. Although the increased perfection of philosophical apparatus has superseded some of his methods of observation, there can be no doubt that his labours imparted more of scientific character to meteorology than it had ever received before. His classification of clouds is the one still recognised at all observatories,[1] and remains an evidence of the quick eye he had for form and colour, and of the daily labour which was to him a labour of love. One who knew him well in the latter part of his life says, "Those who lived with him will not soon forget his interest in the appearance of the sky. Whether at morning, noon, or night, he would go out to look around on the heavens, and notice the changes going on. His intelligent remarks and pictorial descriptions gave a character to the scene never before realised by some. A beautiful sunset was a real and intense delight to him; he would stand at the window, change his position, go out of doors, and watch it to the last lingering ray; and long after he ceased, from failing memory, to name the 'cirrus,' or 'cumulus,' he would derive a mental feast from the gaze, and seem to recognise old friends in their outlines."

Sharing in the active beneficence of the Society of Friends, Luke Howard readily aided endeavours for the religious and moral as well as the material welfare of the community. Not least important among these was the seeking to mitigate by pecuniary means the sufferings of the Germans during the campaigns immediately preceding the first abdication of Napoleon. In Ackworth school—a well known establishment of the Friends—he took a lively interest; and to participate the more directly therein, as well as to offer hospitality to the annual visitors to the school, he bought Ackworth Villa estate in 1823, making it his summer residence, and Tottenham his winter residence, during the greater part of his life.

In 1796 Luke Howard married Mariabella Eliot, a member of the same

[1] Written in 1864.

Society with which he was himself connected. Of their family of seven children two sons only survived their parents. About his eightieth year he was much enfeebled by alarming attacks of illness; and the death of his wife following, after a union of fifty-six years, added sorrow to his weakness. Henceforward his life was a subdued waiting for the end. He died at Tottenham on the 21st March 1864.

Besides the works above mentioned he published—

Essay on the Modifications of Clouds, 1832;

Seven Lectures on Meteorology, 1837;

A Cycle of eighteen years in the Seasons of Britain, &c., 1842;

Barometrographia—Twenty years' variation of the Barometer in the Climate of Britain, 1847;

Papers on Meteorology, 1850-54; and

The Yorkshireman, a religious and literary Periodical in 5 Vols., 1833-37.

CLOUDS:
THEIR REPRESENTATION AND MEASUREMENT.

Catalogue of the Fourteenth Exhibition of Instruments,

Held, by permission of the Council of the Institution of Civil Engineers, at 25 Great George Street, Westminster, S.W.

APRIL 10TH TO 20TH, 1894.

INSTRUMENTS FOR ASCERTAINING THE DIRECTION AND HEIGHT OF CLOUDS.

1. **Goddard's Cloud Mirror.** *Exhibited by* F. C. BAYARD, F.R.Met.Soc.
2. **Cloud Mirror.** *Exhibited by* L. P. CASELLA, F.R.Met.Soc.
3. **Circular Cloud Mirror.** *Exhibited by* L. P. CASELLA, F.R.Met.Soc.
4. **Fineman's Nephoscope.** This consists of a tripod standing on levelling screws, bearing a compass needle in a circular brass frame moveable round a vertical axis. The lid of the compass case is formed of a mirror of black glass provided with a small circular window of clear glass through which the point of the needle is observed. The mirror bears on its surface radial lines for the principal points of the compass, and three circles distant (26·8 mm.) from each other. At the extremity of the diameter passing through the window, and opposite to it, is a vertical graduated scale moved by a ratchet wheel and milled head screw. The scale is raised or lowered till the image of a cloud seen at the centre of the mirror exactly coincides with the end of a line passing from the observer's eye through the point of the scale to the centre of the mirror. *Exhibited by the* METEOROLOGICAL COUNCIL.

5. **Nephoscope devised by Lieut.-Gen. R. Strachey, F.R.S.** This consists of a circular mirror enclosed in a brass frame which is marked for eight points and for every 10°. Parallel lines distant 0·4 in. apart are ruled across the mirror, which is moveable round a vertical axis. Levelling screws are fitted to the instrument.
Exhibited by the METEOROLOGICAL COUNCIL.

6. **Nephoscope devised by Mr. F. Galton, F.R.S.** This consists of a circular brass frame standing on levelling screws. The bevelled edge is marked to eight points, and graduated to 10°. On this frame and moveable about a vertical axis is a mirror, and above it, moving with it, is a rectangular frame with five horizontal rods. The images of these horizontal lines can be brought into parallelism with the direction of motion of a cloud. *Exhibited by the* METEOROLOGICAL COUNCIL.

7. **Photo-Nephograph designed by Capt. Abney, F.R.S., for the registration of the velocity and direction of motion of Clouds.** (See *Reports of the Meteorological Council* for the years 1879 and 1881.)
Exhibited by the METEOROLOGICAL COUNCIL.

8. **Model showing manner in which the pair of Photo-Nephographs are mounted for use.** *Exhibited by the* METEOROLOGICAL COUNCIL.

9. **Camera for photographing Clouds and Lightning,** with a mirror of black glass attached. *Exhibited by* A. W. CLAYDEN, F.R.Met.Soc.

10. **Photographic Theodolite for measuring the height of Clouds.**
Exhibited by MM. L. TEISSERENC DE BORT AND G. RAYMOND.

11. **Slide Rule devised by Lieut.-Gen. Strachey, F.R.S., to facilitate the computation of Cloud heights and distances.** This scale is constructed for use with measurements of the azimuth and zenith distances of clouds made from either end of the base of 2,400 feet. It consists of four scales, the upper being that of log. sines, and the lowest that of log. numbers, the log. of 2,400 ft. coinciding with log. sin 90°. The upper slide is graduated with log. sines of small angles on the same scale, and has two index marks, one at 0°34′23″, the log. sin of which is 8·00000, and the other at 5°44′21″, the log. sin of which is 9·00000. The lower slide is graduated with log. tangents Z, the scale corresponding to that of the sines. To use the rule the index of the upper slide is set to the angle A on the upper scale; the index of the lower slide is then set to the angle A-B on the upper slide, and below it on the lower fixed scale will be found the distance in feet, while below the angle Z upon the lower slide will be found the height of the cloud in feet.
Exhibited by the METEOROLOGICAL COUNCIL.

12. **Instrument designed by Sir G. G. Stokes, Bart., F.R.S., for determining the height, and rate, and direction of motion, of Clouds from photographs.** Photographs of a cloud are taken simultaneously by two cameras placed at either end of a measured base, a second set being taken after a given interval, say of 1 or 2 minutes. A print of one of the four negatives thus obtained is placed upon a sheet of paper, upon which cross lines have been ruled to allow of the picture being properly adjusted, and with a needle a prick is made through the position of the point of the cloud which has been selected for measurement: this process is repeated for each of the remaining pictures of the set. The sheet of paper, which now contains four holes, is placed over the square aperture in the diaphragm of the instrument, which is fixed at a distance from the lens at the end equal to the focal length of the camera lens. Another sheet of paper is then placed on the moveable board beyond the diaphragm which, by means of the divided arc attached to it, is set to the zenith distance of the cameras at the time the

photographs were taken. The instrument being now placed so that a strong light is allowed to pass through the lens on to the diaphragm, four spots of light will be formed upon the paper on the board, which being joined will form a parallelogram, two opposite sides of which will give the *drift* of the cloud on the same scale as the other two sides represent the distance between the two cameras. The *direction* of the drift is readily obtained from the position of the one pair of sides relatively to the other, the latter being parallel to the measured base, the bearings of which are of course known. The product of the distance from the lens to the board and the length of the measured base in feet, divided by the length of the side of the parallelogram parallel to the base, gives at once the *height* of the cloud in feet.

Exhibited by the METEOROLOGICAL COUNCIL.

13. **Apparatus for ascertaining the height, and direction, and rate of motion of Clouds from photographs; devised by the late G. M. Whipple, B.Sc.** In this case simultaneous photographs of a cloud are taken by two cameras at either end of a measured base, and fixed in such a way that their optical axes point to the zenith. The dark slides of the cameras carry a pair of fiducial lines at right angles to each other, and adjusted so that one of the lines shall be parallel to the measured base, and these lines are reproduced upon the cloud photographs. The two negatives are superimposed in the sliding frames of the apparatus, which are then moved till the images of the cloud exactly coincide, when the parallax will be given by a line joining the intersections of the fiducial lines. The parallax having been measured by a pair of compasses, the *height* of the cloud can be at once determined by means of the curve *A* (exhibited No. 107). A similar operation is then performed with one of the same negatives, and a second taken in the same camera after the lapse of, say, one minute. The pictures having been made to coincide as before, the distance between the intersections of the fiducial lines will now indicate the *drift* of the cloud. The *direction* of the drift is indicated by the position of the line joining the two intersections relatively to the fiducial line parallel to the base. The *velocity* of the drift, or in other words the rate of motion of the cloud, is found graphically by means of the diagram B exhibited.

Exhibited by the METEOROLOGICAL COUNCIL.

14. **Appliance for estimating the height of Clouds of the Roll Cumulus type by means of their perspective effect.**

Exhibited by R. INWARDS, Pres.R.Met.Soc.

THERMOMETERS.

15. **Hypsometer for measuring mountain heights by the temperature of the vapour of boiling water.** *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

16. **Thermometer for Balloon observations.** A mercurial thermometer with very long cylindrical bulb in mahogany frame.

Exhibited by the METEOROLOGICAL COUNCIL.

17. **Alarm Thermometer by MM. Richard Frères.** This consists of a flat but slightly curved tube filled with liquid, the bottom end of which is fixed. To the upper end is attached a rod which moves an index hand in front of a dial, thus indicating the temperature. There are also two adjustable indices which can be set to any desired temperatures, so that when the indicating hand touches these, electric contact is made and a bell set ringing. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

HYGROMETERS, EVAPORATORS, &c.

18. **Dew Point Calculator.** This consists of a dry and wet bulb thermometer, to each of which is attached a fixed and adjustable index connected with a pointer for showing on an adjoining scale the temperature of the dew point. *Exhibited by* J. F. SPONG, M.R.C.S.

19. **Inverted Tube Hygrometer.** This arrangement dispenses with the water vessel beneath the wet bulb thermometer; and also registers the amount evaporated from the surface of the bulb, from which the amount of evaporation per square foot for small surfaces can be obtained.
Exhibited by H. HAINSBY.

20. **Vapour Condensor.** This indicates the hygrometric condition of the air by the amount of condensation of vapour on the surface of the plate at the time of observation; also the probable rainfall for the following 24 hours, the face of the plate becoming wet in proportion to the amount of moisture prevailing at the time. *Exhibited by* H. HAINSBY.

21. **Compensating Siphon Evaporator for large water surfaces.** This apparatus being connected by a pipe with any sized tank desired, enables an observer to see by the siphon gauge the rate of evaporation from the large tank, and also the amount of evaporation, without any alteration in the volume of water in the tank. It can also be used as a rain gauge on a large scale if required. *Exhibited by* H. HAINSBY.

22. **Louvred Glass Evaporator.** This evaporator is constructed entirely of glass, in order to permit access of the sun's rays to influence the evaporation of the water contained therein. It is surmounted by a louvred glass hood to protect the water from rain, birds, &c., but this allows the free circulation of air through it. The contents can be measured by the usual means.
Exhibited by DR. W. G. BLACK, F.R.Met.Soc.

MARINE INSTRUMENTS.

23. **Model of Bottle for collecting samples of sea water from moderate depths.** This instrument is intended for use where the sea-disturbance is so great as to make the action of slip water bottles uncertain. At either end of the cylindrical bottle is a tap, tubes from which terminate close together above the bottle, pointing upwards. The taps are closed by extending a spring and hooking the upper rod to the catch, and the instrument is let down to the required depth. A "Rung" messenger sent down the line relieves the catch and opens both taps, admitting water and allowing air to escape. As the two tubes are in the same horizontal plane there is no tendency for the water to change while the bottle is brought to the surface.
Exhibited by H. N. DICKSON, F.R.Met.Soc.

24. **Keating's Hydrometer.** *Exhibited by* J. J. HICKS, F.R.Met.Soc.

ANEMOMETERS.

25. **Dines's Pressure Tube Anemometer.** Recording pattern. (See *Quarterly Journal*, Vol. XVIII. p. 165).
Exhibited by R. W. MUNRO, F.R.Met.Soc.

26. **Dines's Pressure Tube Anemometer, indicating the velocity at sight and also registering the maximum.** (See *Quarterly Journal*, Vol. XIX. p. 16). *Exhibited by* R. W. MUNRO, F.R.Met.Soc.

27. **Dines's Pressure and Velocity Gauge** for use with the Tube Anemometers. The instrument shows on the scale the greatest velocity that has occurred since it was last set by means of the level of the water in the glass tube. It is set by removing the plug and pouring water into the funnel at the top until the water begins to flow from the opening at the side. The plug is then replaced, and the quantity of water forced out by the wind leaves a record of the maximum force that has occurred. *Exhibited by* R. W. MUNRO, F.R.Met.Soc.

28. **Capell-Davis Anemometer for ascertaining velocities over 80 ft. per second.** This instrument is designed to test such high velocities as would endanger the Biram or Davis's self-timing Anemometer. The instrument is 4 ins. in diameter and reads to ten million feet.
Exhibited by Messrs. JOHN DAVIS & SON.

TRAVELLERS' INSTRUMENTS.

29. **Goad's Geodetic Altazimuth.** This is an adaptation of the Galton Pocket Altazimuth for use as a hand instrument in exploring work, as well as for surveys requiring the greatest precision either on the surface or in mines and other workings. In this instrument the compass box is so connected to the clinometer drum that it can either be folded flat against the end of the same, or turned to a position in which the axis of the compass is so mounted that it may be rotated about the axis of the clinometer, a circle graduated to correspond to the clinometer scale being provided to enable the compass to be adjusted to a horizontal position by reference to the reading of the clinometer.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

30. **Universal Sun Dial** for any position north or south of the equator with 2½ in. divided circle. *Exhibited by* L. P. CASELLA, F.R.Met.Soc.

31. **Artificial Horizon** of parallel black glass, with level and adjusting screws.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

32. **Artificial Horizon,** mounted on gimbals.
Exhibited by L. P. CASELLA, F.R.Met.Soc.

33. **Hicks's Circular Level,** with the fluid hermetically sealed.
Exhibited by J. J. HICKS, F.R.Met Soc.

BAROMETERS.

34. **Bartrum's Open Scale Barometer.** *Exhibited by* J. J. HICKS, F.R.Met.Soc.

35. **Calendar's Compensating Open Scale Barometer.**
Exhibited by J. J. HICKS, F.R.Met.Soc.

SKETCHES AND PHOTOGRAPHS OF CLOUDS.

36. **Portrait of Luke Howard, F.R.S.** Born November 28th, 1772; died March 21st, 1864. Drawn by Bedford about 1843. (See frontispiece.)
Exhibited by W. D. HOWARD, F.R.Met.Soc.

37. **Clouds gathering for a Thunderstorm.** An original sketch by the late Luke Howard, F.R.S. "A sky full of specimens of the peculiar forms assumed by the clouds when gathering for a thunderstorm. (The dense

clouds in front, though characteristic as forms, are not enough shrouded in a gloomy distance.) The Nimbus behind, on the left, is better placed, and shows crossed, as is at times the case, by a dense cirro-stratus. The Cirro-cumulus, next above, is highly characteristic in its structure; and the large dense Cirrus above belongs equally to approaching thunder. March 1849." *Exhibited by* W. D. HOWARD, F.R.Met.Soc.

38. **The Commencement of a Stratus.** An original sketch by the late Luke Howard, F.R.S. "This picture presents, mixed with the objects common to a landscape, the commencement of a Stratus, or evening mist, creeping, as it rises, through the valley, to become shortly a dense body of cloud, resting with a lever surface on the ground like a lake of water; and possibly, on the morrow, covering the country with a fog. Above, in the blue sky, are features of Cirrus. March 1849."
Exhibited by W. D. HOWARD, F.R.Met.Soc.

39. **Rough Models illustrating the Forms of Clouds.**
Exhibited by F. GASTER, F.R.Met.Soc.

40. **Cloud Photographs taken by Mons. Paul Garnier at the Observatory, Boulogne-sur-Seine, 1889.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

41. **Cloud Photographs taken at the Santis Observatory, Switzerland.**
Exhibited by PROF. A. RIGGENBACH-BURCKHARDT.

42. **Thunder Clouds, August 1st, 1890, taken from the Santis Observatory, Switzerland.** (See *Meteorologische Zeitschrift*, Band 8, 1891, p. 96.) *Exhibited by* PROF. A. RIGGENBACH-BURCKHARDT.

43. **Thunderstorm at Sydney, May 31st, 1892.** A series of six photographs taken by Mr. H. C. Russell, F.R.S., between 3.0 and 4.59 p.m.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

44. **Festooned Cumulus.** Two photographs showing part of a storm cloud which passed over Sydney, New South Wales, January 18th, 1893.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

45. **Clouds preceding a "Southerly Burster"** at Sydney, New South Wales, November 13th, 1893, 6 p.m. *Exhibited by* H. C. RUSSELL, F.R.S.

46. **The Cloud-Roll of the "Southerly Burster"** at Sydney, New South Wales, November 13th, 1893, 7 p.m. *Exhibited by* H. C. RUSSELL, F.R.S.

47. **Cloud Photographs.** *Exhibited by* DR. F. G. SMART, F.R.Met.Soc.

48. **Cloud Photographs taken at Paris.** *Exhibited by* MONS. A. ANGOT.

49. **Thunder Clouds.** Taken by Dr. F. Drewitt in Northamptonshire, July 1887. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

50. **Tornado Cloud, Jamestown, Dakota, June 6th, 1887.** Two photographs. The cloud funnel was 12 miles to the north.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

51. **Tornado Cloud.** Taken in the storm of June 22nd, 1888, showing the spiral-shaped funnel trailing at a considerable altitude in the air at the other side of a lake, New Hampshire, U.S.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

52. **Collection of the Cloud Photographs,** which are reproduced in Singer's *Cloud Atlas*, and which are arranged according to the classification proposed by the Hon. R. Abercromby and Dr. H. H. Hildebrandsson.
Exhibited by DR. K. SINGER.

53. **Photographs of Cirrus and Cirro-cumulus Clouds.**
Exhibited by Mons. G. Raymond.

54. **Set of Cloud Photographs.** *Exhibited by* Dr. A. Sprung.

55. **Clouds taken at the Vatican Observatory, Rome,** under the direction of Padre F. Denza, by Signor Mannucci.
Exhibited by the British Association Committee on the Application of Photography to Meteorology.

56. **Cloud Photographs illustrating Capt. D. Wilson-Barker's proposed Cloud Nomenclature.**
Exhibited by Capt. D. Wilson-Barker, F.R.Met.Soc.

57. **Cloud types: Cirrus, Cumulus, and Cirro-stratus.**
Exhibited by Birt Acres.

58. **Clouds taken by reflection from a black glass Mirror,** on Mawson and Swan's Photo-mechanical plates.
Exhibited by A. W. Clayden, F.R.Met.Soc.

59. **Cloud Photographs.** Two frames. *Exhibited by the* Kew Committee.

60. **Three framed Photographs of Clouds.** *Exhibited by* L. Cohen.

61. **Frames containing Photographs of Cloud Subjects.**
Exhibited by Col. H. M. Saunders.

62. **Poey's Classification of Clouds.** *Exhibited by* G. J. Symons, F.R.S.

63. **Illustrations of Cloud-forms,** being first proofs from Capt. FitzRoy's *Voyage of the Beagle*, 1839.
Exhibited by the Meteorological Council.

64. **Representation of the Forms of Clouds,** given in Admiral FitzRoy's *Log Book*. *Exhibited by the* Meteorological Council.

65. **Sketches of Cloud Forms by the late Mrs. Toynbee.**
Exhibited by the Meteorological Council.

66. **Typical varieties of Clouds.** Illustrating the Rev. W. Clement Ley's Lecture on "Clouds and Weather Signs" in *Modern Meteorology*, 1879.
Exhibited by the Royal Meteorological Society.

67. **Drawing showing typical Forms of Clouds** with their names and usual height in the atmosphere, and a scale of feet and miles, with sketches of comparative heights of mountains, &c. for comparison.
Exhibited by R. Inwards, Pres.R.Met.Soc.

68. **Plate showing method of measuring Heights of Cloud.** (From J. F. Glöckner's *De Pondere Nubium*, 1722).
Exhibited by G. J. Symons, F.R.S.

69. **Illustrations of Cloud-forms.** From *On the Modifications of Clouds, &c.*, by Luke Howard. First edition, 1803.
Exhibited by G. J. Symons, F.R.S.

70. **Hellmann's "Neudrucke von Schriften und Karten uber Meteorologie und Erdmagnetismus."** No. 3. Containing reprint of Luke Howard's memoir "On the Modifications of Clouds," 1803, with facsimiles of the three plates. *Exhibited by* Dr. G. Hellmann.

71. **Illustrations of Cloud-forms.** From *Researches about Atmospheric Phænomena*. By T. Forster. Third edition. 1823.
Exhibited by G. J. Symons, F.R.S.

72. **Illustrations of Cloud-forms.** From *Meteorology.* By G. Harvey, F.R.S. *Encyclopædia Metropolitana.* 1834.
Exhibited by G. J. SYMONS, F.R.S.

73. **Illustrations of Primary and Secondary Cloud-forms,** from Maury's *Sailing Directions*, Eighth edition, 1859.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

74. **Illustrations of Cloud-forms.** From *Essay on the Modifications of Clouds*, by Luke Howard, F.R.S. Third edition, 1865.
Exhibited by G. J. SYMONS, F.R.S.

75. **Illustrations of Cloud-forms.** From *Clouds, their Forms and Combinations.* By Elijah Walton. Third edition, 1873.
Exhibited by the METEOROLOGICAL COUNCIL.

76. **Illustrations of Cloud-forms.** From "Atlas donnant les principales formes des nuages avec un résumé de leur classification;" par P. Weilbach. 1881. *Annuaire de l'Institut Météorologique du Danemark*). *Exhibited by* G. J. SYMONS, F.R.S.

77. **Illustrations of Cloud-forms.** From *Le Monde Physique*: par A. A. Guillemin. Tome V. La Meteorologie. 1885.
Exhibited by G. J. SYMONS, F.R.S.

78. **"Measurement of Cloud Heights and Velocities at the Blue Hill Meteorological Observatory,"** being Part III. of Vol. XXX. *Annals Harvard College Observatory. Exhibited by* A. L. ROTCH, F.R.Met.Soc.

79. **Singer's "Wolkentafeln."** *Exhibited by* DR. K. SINGER.

SKETCHES AND PHOTOGRAPHS OF METEOROLOGICAL PHENOMENA.

80. **Lightning, June 28th, 1892.** Two enlargements of photographs taken by Mr. G. Corden at Croydon, 8.45 to 9 p.m.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

81. **Lightning, June 28th, 1892.** Enlargement of photograph taken by Mr. R. H. Pickel at Bexley at 10.30 p.m.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

82. **Lightning at Sydney, December 7th, 1892.** Two photographs taken by Mr. H. C. Russell, F.R.S., at the Observatory. The point at which the flash struck the water was 2,000 ft. from the camera.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

83. **Cedar Tree struck by Lightning, July 18th, 1892,** at Tyntesfield Park, Wraxall, near Bristol.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

84. **Frost Fronds on Window.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

85. **Site of Waterspouts at Langtoft, near Driffield, June 9th, 1888, and July 3rd, 1892.** (See *Quarterly Journal of the Royal Meteorological Society*, Vol. XIX., p. 1.)
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

86. **After the Flood at Langtoft, near Driffield, July 3rd, 1892.** (Two photographs.) *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

87. **Hailstones (actual size) which fell at Richmond, Yorkshire, July 8th, 1893.** (Two photographs.) Some of the hailstones were more than 2 ins. in diameter.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

88. **Damage by Hail to Conservatory in the Bog Valley Gardens, Harrogate, July 8th, 1893.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

89. **Old Sulphur Well, Harrogate.** This photograph, which was taken in November 1893, shows the marks made upon the lead roof by the hailstones that fell during the terrific thunderstorm on July 8th.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

90. **Iron Roofing perforated by Hail,** October 13th, 1892, at Tulcumbah, New South Wales.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

91. **Atmospheric Phenomena** consisting of coloured Solar Halos, Parhelia, a white Circle around the sun, and an Anthelion, as seen at Gosport, March 29th, 1848. Drawn by Mr. J. H. Maverley.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

92. **Solar Halos seen at Weymouth, April 28th, 1883.** Coloured sketch by Mr. J. T. See. *Exhibited by* W. MARRIOTT, F.R.Met.Soc.

93. **Photograph of Rainbow.** *Exhibited by* REV. F. C. LAMBERT.

94. **Snow Scene, Tunbridge Wells, April. 1892.**
Exhibited by DR. F. G. SMART, F.R.Met.Soc.

95. **Photograph of Fog on January 12th, 1888,** taken from the top of the Worcestershire Beacon (1,390 ft. above sea-level), about 700 ft. above the general level of the fog which covered the whole of the surrounding country. Above the fog there was bright sunshine and clear sky.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

96. **Twilight and After-Glow effects at Chelsea, November 26th, 1883.** (See *Report of the Krakatoa Committee of the Royal Society*, 1888).
Exhibited by H. S. WALLIS, F.R.Met.Soc.

97. **Diagrams illustrating Krakatoa Volcanic Dust** collected 1,000 miles from the place of eruption. Enlarged 10,000 diameters.
Exhibited by W. F. STANLEY, F.R.Met.Soc.

98. **"The Daily Graphic." Drawings used to illustrate the Weather Forecasts.** *Exhibited by* C. HARDING, F.R.Met.Soc.

PHOTOGRAPHS AND DIAGRAMS OF INSTRUMENTS.

99. **Daguerreotype showing the collection of apparatus for Mr. Welsh's Balloon Ascents at Vauxhall Gardens, July 1852,** with likenesses of several members of the Kew Committee of that date.
Exhibited by the KEW COMMITTEE.

100. **Photographs of Mr. J. Glaisher, F.R.S., and Mr. H. Coxwell in the car of a Balloon, with meteorological instruments in position.**
Exhibited by G. J. SYMONS, F.R.S.

101. **Photograph showing the arrangement of the Meteorological Instruments** adopted for the ascents of the free balloon belonging to the "Deutscher Verein zur Forderung der Luftschiffahrt."
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

102. **Cloud Equatorial constructed by Dr. Nils Ekholm, Hon.Mem.R.Met.Soc.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

103. **Photograph of Theodolite used in the determination of Cloud altitudes** at the Blue Hill Observatory, Mass., U.S.A.
Exhibited by A. L. ROTCH, F.R.Met.Soc.

104. **Photograph of Plotting Machine** for graphical solution of data obtained with the above Theodolite (No. 103).
Exhibited by A. L. ROTCH, F.R.Met.Soc.

105. **Photograph of Pole Star Recorder** in use at the Blue Hill Observatory for recording cloudiness at night.
Exhibited by A. L. ROTCH, F.R.Met.Soc.

106. **Two Photographs of "Trails" by Pole Star Recorder.**
Exhibited by A. L. ROTCH, F.R.Met.Soc.

107. **Diagrams designed by Lieut.-Gen. Strachey, F.R.S., to facilitate the calculation of the height and motions of Clouds from photographs.**
Diagram A is arranged to give the *height* of the cloud, the heights being indicated by the abscissæ on a scale in which the length of the base between the two cameras is equal to the focal length of the camera lens. The parallax obtained in the way explained under Exhibit No. 13 is measured on the ordinates of the curve, and the corresponding height is at once read off below.

Diagram B gives the *rate of motion* of the cloud. The line A B represents the measured base between the two cameras upon the same scale as is used to represent one mile upon the larger diagram of proportional velocities. The drift obtained from the negatives, in the manner explained under Exhibit No. 13 is marked off upon the lines A C and B D measuring from A B, and the parallax is marked off upon the line A B, measuring from A; a line is then drawn from the point on A C through that on A B to the line B D, and the distance from the point previously marked off on B D to the extremity of this line is taken off and measured on the diagram of relative velocities, upon the vertical line corresponding to the interval in seconds which had elapsed between the taking of the two photographs.
Exhibited by the METEOROLOGICAL COUNCIL.

108. **Records of Velocity of the Wind by Dines's Pressure Tube Anemometer** at Oxshott, Surrey, December 12th and 13th, 1893; February 7th, 11th; and March 2nd and 27th, 1894.
Exhibited by W. H. DINES, F.R.Met.Soc.

109. **Drawing of a suggested form of Barometer** designed to give readings already corrected for capacity, capillarity, temperature and height above sea level. The temperature correction is obtained by reading the thermometer which has its bulb immersed in the mercury of the cistern. The horizontal screw head at the top of the instrument is then turned until the pointer on the horizontal scale points to the temperature. This has the effect of depressing or raising the vernier by means of an inclined plane so as to deduct or add the proper correction for temperature. The inclination of the plane supporting the vernier changes with its rise on the scale by means of diagonal slots on the brass frame of the instrument. These can be adjusted when the instrument is made.

The capacity correction is made by a milled head at the bottom or cistern end of the instrument, and a glass plunger is caused to immerse itself in the mercury until it just brings the level of the same to the ivory point which is fixed above its surface. The capillarity corection is not needed with so large a bore. The correction for heigt above sea level is provided by shortening the instrument by means of the screws in the middle of its height, and, of course, the temperature adjustment must be made to correspond when the instrument is first adjusted for its station. *Exhibited by* R. INWARDS, Pres.R.Met.Soc.

110. **Chart for reducing readings of Metallic Barometers** to the temperature of 32°; by Mr. E. H. Griffiths.
Exhibited by J. J. HICKS, F.R.Met.Soc

LANTERN SLIDES AND TRANSPARENCIES.

111. **Clouds taken mostly at the Santis Observatory, Switzerland.** (26 Slides.) *Exhibited by* PROF. A. RIGGENBACH-BURCKHARDT.

112. **Clouds taken by reflection from a black glass Mirror.** (24 Slides.) *Exhibited by* A. W. CLAYDEN, F.R.Met.Soc.

113. **Slides illustrating Capt. D. Wilson-Barker's proposed Cloud Nomenclature.** *Exhibited by* CAPT. D. WILSON-BARKER, F.R.Met.Soc.

114. **Clouds from Photographs taken by Mons. Paul Garnier,** at the Observatory, Boulogne-sur-Seine, 1889.
Exhibited by W. MARRIOTT, F.R.Met.Soc.

115. **Clouds comprising Cirrus, Cirro-cumulus, Cumulus and Stratus.**
Exhibited by BIRT ACRES.

116. **Slides and Transparencies showing the movements of Cumulus and Cirrus Clouds at intervals of 30 seconds.** *Exhibited by* BIRT ACRES.

117. **Slides of Clouds.** Most of these are Upper Clouds with a few Cumulus.
Exhibited by A. D. HALL.

118. **Slides of Clouds.**
Exhibited by REAR-ADMIRAL J. P. MACLEAR, F.R.Met.Soc.

119. **Clouds** (4 slides). *Exhibited by* A. STROH.

120. **Clouds** (3 slides). *Exhibited by* H. E. DAVIS.

121. **Clouds** (2 slides). *Exhibited by* L. COHEN.

122. **Clouds** (3 slides). *Exhibited by* T. C. WHITE.

123. **Clouds** (6 slides). *Exhibited by the* SCIOPTICON CO.

124. **Aurora Borealis** (2 slides). *Exhibited by the* SCIOPTICON CO.

125. **Festooned Cumulus at Sydney, New South Wales, January 18th, 1893.** *Exhibited by* W. MARRIOTT, F.R.Met.Soc.

126. **Hailstones which fell at Richmond, Yorkshire, July 8th, 1893.** Taken by Mr. J. H. Metcalfe.
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

127. **Man's Hat damaged by Hailstones at Richmond, Yorkshire, July 8th, 1893.** *Exhibited by* W. MARRIOTT, F.R.Met.Soc.

128. **Iron Roofing perforated by Hail** at Tulcumbah, New South Wales, October 13th, 1892. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

129. **Lightning Flashes, at Croydon, June 28th, 1892.** Taken by Mr. G. Corden. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

130. **Lightning Flashes, June 28th, 1892.** Taken at Bexley by Mr. R. H. Pickel. *Exhibited by the* ROYAL METEOROLOGICAL SOCIETY.

131. **Trees struck by Lightning in the neighbourhood of Bristol, 1892.**
Exhibited by the ROYAL METEOROLOGICAL SOCIETY.

132. **Hoar Frost on Grass;** taken by Rev. J. M. Coates, at Welton-le-Wold, Lincolnshire. *Exhibited by* W. MARRIOTT, F.R.Met.Soc.

133. **Slides of Clouds.** *Exhibited by the* KEW COMMITTEE.

134. **Two Slides showing the Cloud Camera in position.** *Exhibited by the* KEW COMMITTEE.

135. **Slides of Clouds.** *Exhibited by* F. GASTER, F.R.Met.Soc.

136. **Slides of Clouds.** *Exhibited by* COL. H. M. SAUNDERS.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

March 21st, 1894.

Ordinary Meeting.

RICHARD INWARDS, F.R.A.S., President, in the Chair.

HUGH CHARLES KIDDLE, Public School, Walbundrie, New South Wales; and SIDNEY RICHARD LOWCOCK, Assoc.M.Inst.C.E., 35 Waterloo Street, Birmingham, were balloted for and duly elected Fellows of the Society.

It was announced that the Society, in conjunction with the Sanitary Institute, had arranged for a course of six Lectures on "Meteorology in relation to Hygiene," to be given at the Parkes Museum, Margaret Street, W., as follows:—

April 23rd. Instruments and Observations and their Representation. G. J. SYMONS, F.R.S.

„ 26th. Temperature of Air, Soil and Water. Dr. H. R. MILL, F.R.S.E.

„ 30th. Barometric Conditions and Air Movements. R. H. SCOTT, M.A., F.R.S.

May 3rd. Moisture, its Determination and Measurement. W. MARRIOTT, F.R.Met.Soc.

„ 7th. Climate in Relation to Health, and Geographical Distribution of Disease. C. THEODORE WILLIAMS, M.A., M.D., F.R.C.P.

„ 10th. Fog, Clouds and Sunshine. F. GASTER, F.R.Met.Soc.

The fee for the course would be half-a-guinea. Fellows of the Society would be admitted without payment.

The following communications were read:—

"RELATION BETWEEN THE MEAN QUARTERLY TEMPERATURE AND THE DEATH RATE." By W. H. DINES, B.A., F.R.Met.Soc. (p. 173.)

"DURATION AND LATERAL EXTENT OF GUSTS OF WIND, AND THE MEASUREMENT OF THEIR INTENSITY." By W. H. DINES, B.A., F.R.Met.Soc. (p. 180.)

"ON THE CALCULATION OF PHOTOGRAPHIC CLOUD MEASUREMENTS." By Dr. K. G. OLSSON. (p. 187.)

Mr. R. H. SCOTT, F.R.S., read the following

"NOTE ON UNUSUALLY SUDDEN BAROMETRICAL OSCILLATIONS AND HIGH WIND VELOCITY IN THE BRITISH ISLES IN FEBRUARY 1894."

THE storm which passed over the North of Scotland on the night of February 23rd-24th, was not marked by any very high wind velocity at our station at Deerness in the Orkneys, as will be seen from the figures in the left-hand portion of Table I., giving the hourly velocities and direction for the two days.

The behaviour of the barometer at the three stations on the north-west and north coasts was, however, most remarkable, as will be seen from Table II.

TABLE I.

Hour.	Deerness. February 1894. 23rd. Velocity. Miles.	Deerness. February 1894. 23rd. Direction.	Deerness. February 1894. 24th. Velocity. Miles.	Deerness. February 1894. 24th. Direction.	Fleetwood. February 1894. 11th. Velocity. Miles.	Fleetwood. February 1894. 11th. Direction.	Fleetwood. February 1894. 12th. Velocity. Miles.	Fleetwood. February 1894. 12th. Direction.
1 a.m.	30	SW by S	38	W by N	7	N by E	81	W by S
2 ,,	32	WSW	36	W	3	NNE	80	,,
3 ,,	35	SW by S	36	WSW	3	,,	86	W
4 ,,	27	SW	37	W by S	3	,,	85	,,
5 ,,	21	SW by W	34	WSW	5	,,	90	W by N
6 ,,	21	SW by S	32	W by S	24	W by S	83	WNW
7 ,,	26	SSW	29	WSW	38	SW by W	80	,,
8 ,,	32	,,	32	W by S	42	SW	77	,,
9 ,,	32	,,	25	,,	47	,,	61	W by N
10 ,,	35	,,	38	WSW	49	,,	65	,,
11 ,,	35	,,	24	W by S	49	,,	62	WNW
Noon	34	,,	39	WSW	50	,,	65	,,
1 p.m.	33	S by W	34	,,	49	,,	61	W by N
2 ,,	36	S by E	33	W	52	,,	60	W
3 ,,	42	,,	33	W by N	53	,,	52	WNW
4 ,,	44	,,	30	W	57	,,	52	W by N
5 ,,	51	SSE	20	W by N	61	,,	49	WNW
6 ,,	55	,,	23	W	67	,,	50	,,
7 ,,	54	S by E	28	,,	69	SW by S	52	,,
8 ,,	40	,,	29	,,	70	,,	46	,,
9 ,,	58	WNW	29	W by S	65	SW	49	,,
10 ,,	67	,,	31	WNW	66	SW by W	47	,,
11 ,,	50	,,	26	W	77	W by S	41	,,
Midnight	43	W by N	27	W	76	,,	41	,,

TABLE II.

February 23, 1894.	Malin Head. ins.	Stornoway. ins.	Sumburgh. ins.
6 a.m.	29·74	29·45	29·39
7 ,,	·70	·40	·39
8 ,,	·65	·38	·40
9 ,,	·56	·40	·39
10 ,,	·50	·35	·37
11 ,,	·42	·30	·32
Noon	·33	·22	·29
1 p.m.	·20	·14	·20
2 ,,	29·04	29·04	·03
3 ,,	28 95	28·93	29·05
4 ,,	29·02	·84	28·98
5 ,,	·03	·70	·92
5.30 p.m.		·50	
6 ,,	·18	·58	·85
7 ,,	·20	·75	·68
8 ,,	·21	·87	·50
9 ,,	·22	·92	·40
10 ,,	·23	28·95	·37
11 ,,	·24		·35
Midnight	29·25		28·50

These figures show that at Stornoway the barometer fell 0·20 in., from 28·70 ins. to 28·50 ins., in the half hour from 5 to 5.30 p.m., a rate of fall rarely equalled in these islands.

Another matter also seems to merit notice, an actual run of an anemometer of 90 miles within an hour is rare. This velocity was overpassed for some hours at Deerness in the storm of November 18th-19th, 1893 (*Quarterly Journal*, Vol. XX. p. 48), and it was reached at Fleetwood at 5 a.m. February 12th, as will be seen from the right-hand portion of Table I.

Capt. D. WILSON-BARKER remarked that he had once seen the barometer rise ·06 in. in twenty minutes when in the neighbourhood of the Falkland Islands.

Mr. F. J. BRODIE said that the weather during December 1893 to February 1894 had been remarkable for the almost constant flow of large depressions along our extreme northern coasts, the barometer in the north of Scotland having been below 28·50 ins. on no fewer than five different occasions. The general effect was well shown in the difference between the mean pressures at Sumburgh Head and London; the normal differences being in December 0·28 in., in January 0·33 in., in February 0·21 in., and the average for the quarter 0·27 in.; whereas during the past winter the figures had been, December 0·51 in., January 0·40 in., February 0·62 in., and the average for the quarter 0·51 in. The mean gradient over the United Kingdom for the entire winter was therefore nearly twice as steep as usual, a fact which affords a simple key to the general mildness and storminess of the season, and to its partial immunity from fogs.

April 18th, 1894.

Ordinary Meeting.

RICHARD INWARDS, F.R.A.S., President, in the Chair.

BIRT ACRES, Clovelly Cottage, Barnet;
JOHN FARRAH, 3 Crescent Road, Harrogate; and
KAUFMANN ISRAEL MARKS, 174 Sutherland Avenue, Maida Vale, W.,
were balloted for and duly elected Fellows of the Society.

The following communication was read:—

"SOME PHENOMENA OF THE UPPER AIR." By RICHARD INWARDS, F.R.A.S., President. (p. 199.)

On the motion of Mr. G. CHATTERTON, seconded by Mr. S. W. SILVER, the thanks of the Society were given to the Exhibitors for the loan of their instruments, &c.

The meeting was then adjourned for a short time in order to allow the Fellows and their friends an opportunity of inspecting the Exhibition of Instruments, Drawings, and Photographs relating to the Representation and Measurement of Clouds, which had been arranged in the rooms of the Institution of Civil Engineers. (p. 217.)

At 9.30 p.m. a Lantern Display was given of slides illustrating various meteorological phenomena, Mr. W. MARRIOTT giving a description of the various pictures.

CORRESPONDENCE AND NOTES.

Whirlwinds on May 26th, 1894.—The following accounts of two whirlwinds are taken from the *Times*:—

"A WHIRLWIND IN HEREFORDSHIRE.—The Rev. H. C. Sturges writes to us from Bodenham Vicarage, Leominster:—'If a whirlwind be a violent movement of the atmosphere in a circular direction about an axis, we certainly had one in this village on Saturday, May 26th, between 1 and 2 p.m. Two dense thunder clouds were seen approaching with their separate storms at about 1.30 p.m., the one from the north-west the other from the north-east. These appeared to meet n the centre of this village, which is in one of the Lugg valleys, eight miles north of Hereford. Within a radius of about 300 yards there was such a violent movement of the atmosphere in a circular direction that trees were cut off at the stem, huge branches off the elm trees were carried 50 yards or more, and tiling was lifted off the buildings. At the same time sheets of hailstones were hurled against the windows from all points of the compass. Beyond the radius of the storm vortex the weather was calm and bright, so that our friends three-quarters of a mile off to the west, who witnessed us enveloped in an inky blackness, suffered nothing. A pond in the village is almost entirely choked with fallen timber, the trees having fallen against each other. Is it not a most unusual thing in this country for the area of a storm of wind of such violence to be so exceedingly limited in extent? I ought to add that some wind and a great deal of hail was experienced to the east of us, but not wind sufficient to break a branch off a tree.'"

"THE WHIRLWIND.—Mr. Richard P. Dansey, of Ludlow, writes to us:—'Having seen in your columns a letter from the Rev. H. C. Sturges, describing a whirlwind near Leominster on May 26th, I trust you will be able to find space for an account of another cyclone, or whirlwind, which occurred near Ludlow on the same date, and at approximately the same time, the description of which agrees in every particular with that given by your correspondent. About 1 p.m. on Saturday the 26th, a very heavy storm broke over the Clees (whose highest point rises to 1,805 ft. above the sea), accompanied with incessant thunder and lightning. In five minutes, or less, these hills were quite white and completely covered with snow down to about 1,000 ft. high, while the lightning all the time was most vivid and the thunder very loud. A few minutes afterwards a sort of secondary storm appeared to be forming in the north about a mile and a half away. One could see sheets of hail sweeping out of the dark clouds, while clouds of dust were swept across the fields which evidently indicated a tremendous wind, as, indeed, proved to be the case. The path of the cyclone, for such indeed it was, seemed about 300 yards wide, and it advanced towards us with tremendous rapidity, and even as it came we could trace its passage by the trees and branches which could be seen falling in the distance as the cyclone approached. Suddenly it reached us together with a downpour of huge hailstones and lumps of ice. The centre or vortex of the whirlwind seemed to pass directly over our house, and swept everything before it. We saw three trees fall in the garden—including a magnificent fir, 80 ft. in height—at the same moment and within 60 yards of each other, while others were bent double; a roof was lifted bodily off a French barn and carried over fields and hedges a distance of 200 yards; big, heavy glass lights were blown off cucumber frames; a large garden bench was whirled through the air and deposited upside down: hens were caught off their feet and sent literally flying through the air, and the air was filled with branches and *débris* to such a degree that, coupled with blinding snow, which had succeeded the hail, and was whirling round and round, one could not see more than 80 yards. The wind and storm had all passed in a very few minutes, the extreme height of the cyclone being limited to about 30 seconds. In every field could be seen oaks or chestnuts or other prostrate trees, and in places, also, the snow still lay where it had drifted. The whirlwind seemed to go up into the air about half-a-mile beyond us, coming down to the ground again about 1½ mile to our south, where it again wrought enormous destruction, though outside its narrow path not a tree was touched. We all thought the gale of Sunday, February 11th, severe, even

though it only blew down half-a-dozen trees in our vicinity, but it was merely a gentle breeze compared with the awful intensity of the cyclone experienced on the 26th, which must have uprooted hundreds of trees in its path, narrow though it was.'"

Electric Phenomena during Thunderstorms.—In a letter to the *Standard* of May 31st, Mr. C. S. Du Riche Preller, writing from Baden, Switzerland, said:—"Some exciting and horribly beautiful, but also very dangerous, electric phenomena were observed in the picturesque Canton of St. Gall, on the evening of the 25th inst., during a thunderstorm of extraordinary violence, accompanied by a deluge of rain. The large 'village' of Gossau, about seven miles from the town of St. Gall, derives its electric supply for lighting and motive power for industrial purposes from a hydro-electrical central station, situated at a distance of eight miles, by a high tension transmission, with transformer stations in the village. The thunderstorm, accompanied by violent lightning discharges, passed over the place at 5 p.m., and then, driven back by a change of wind, returned, and lasted for several hours. Soon after 5 p.m. all the electric lights went out spontaneously, but the place was illuminated by violent sparks and flashes, which were emitted by the overhead wire system, and ran along the conductors. These phenomena reached their height at the principal transformer station, close to an hotel; for here the high pressure current escaped from the conductors to earth—viz. the ground saturated with rain—the effect being a succession of flashes or continuous blaze, which so endangered the building that the fire brigade had to be called out to protect it. These phenomena continued for several hours, till the electric supply was cut off at the central station, a special messenger on horseback having been despatched thither, for, wonderful to relate, the installation was as yet without telephonic communication. The lightning struck several houses in the village, though without doing harm; but a young man of powerful build, and of local position and great promise—for he was to have been elected Mayor on the very next day—inadvertently touched one of the electric cables, and was instantly killed. The inhabitants of the place might have been spared the terror of these phenomena, and probably no human life would have been lost, if the electric supply had been cut off during the altogether exceptional thunderstorm, as should always be done—and in the United States is done on some electric tramways—in districts visited by violent atmospheric discharges, and where overhead wires are used. Only last summer I witnessed a similar occurrence on the Mont Salève electric railway, near Geneva, where the lightning struck the feed conductor of the line, and thence found its way along the transmission cables to the central station, fully two miles distant, where it passed through the lightning arrester and burnt out one of the huge 1,000 horse-power dynamos. In this case, too, the lightning discharge was only the indirect cause, the direct cause being that the dynamo was running at the time, viz. that the current followed the discharge through the not quite perfect lightning arrester, and 'short-circuited' the dynamo."

Remarkable Flash of Lightning.—Herr O. Hoppe, in a paper "Oberirdische und unterirdische Wirkungen eines Blitzstrahles," which appeared in *Leopoldina*, Vol. XXIX., 1893, gives an account of a very remarkable flash of lightning which occurred on July 20th, 1881, near the town of Clausthal in the Hartz. The house struck was not situated in an exposed position, a church near it, but on a hill above it, escaped. Dr. Hoppe accounts for this by the circumstance that the house struck was standing in a damp, good conducting soil. He remarks that the joists of the house, of dry pine, were torn to splinters, but not set on fire; but where the lightning found nails in damp wood, the ends of the nails were fused and the wood caught fire. From this Dr. Hoppe concludes that iron nails or fastenings should not be used in roof timbers. The residents in the house were sleeping on feather beds, and were all uninjured. The experience of various miners at the level of 1,000 fathoms is given, as tendered in evidence before a commission of inquiry. They evidently felt the same flash as wrecked the house. The paper is worth notice for those who are engaged in lightning rod work.

Evaporation at Kimberley, South Africa.—Mr. R. H. Twigg, M.Inst.C.E., has favoured us with the monthly evaporation at the Kimberley Waterworks,

South Africa, for the three years 1891-1893. The gauge is of wrought iron, 4 feet cube, buried in the ground to within 1 inch of the top; the level of the water inside is kept 2 or 3 inches below the top to allow for the heaviest showers. The gauge is read every day to ·001 inch by means of Twigg's hook gauge.

	1891. ins.	1892. ins.	1893. ins.
January	10·30	11·95	10·34
February	8·59	11·29	10·00
March	6·30	7·51	9·14
April	5·08	6·43	7·79
May	5·05	5·97	6·98
June	3·68	4·00	5·10
July	4·11	5·18	4·68
August	5·30	6·85	6·16
September	8·27	8·33	8·09
October	10·46	8·88	11·00
November	9·08	12·18	10·57
December	10·46	15·84	11·47
Year ...	86·68	104·41	101·32

Drought on the Coast of East Africa.—Mr. W. B. Cracknall, of Zanzibar, in a despatch to the Colonial Secretary, dated May 3rd, 1894, says:—"I have the honour to inform your Lordship that on the coast of East Africa, extending from Mozambique right through the German coast, there has been almost a total absence of the rain usually experienced at this season. In the Island of Zanzibar the rainfall for this year is, up to date, 12·82 ins., in contrast to 34·79 ins. registered up to April 30th last year.

"The South-west wind, which should be blowing strong and fresh, is gentle and variable, and the abnormal heat of the last few months has but slightly abated.

"Fears are entertained of a famine on the coast; and already I am informed the greatest scarcity of food prevails, while the price of rice in the Zanzibar bazaars is much augmented, and most probably the rainfall in the territory of the Imperial British East Africa Company will be irregular and scanty.

"I have troubled your Lordship with this despatch, as it is likely that this state of things may have some relation to the coming South-west monsoon of the Indian Empire."

Rainfall at Aburi, West Africa.—The following are the monthly amounts of rainfall for the three years 1891-93, at the Botanical station, Aburi, on the Gold Coast. The station is 1,400 feet above sea level, and 26 miles from the coast.

	1891. ins.	1892. ins.	1893. ins.
January	2·33	1·59	2·66
February	3·41	1·62	2·98
March	3·98	2·93	5·01
April	6·22	6·35	8·32
May	6·84	9·94	8·02
June	20·03	3 34	2·66
July	3·42	—	8·38
August	·37	·61	9·77
September	·37	—	4·14
October	1·86	9·75	8·92
November	3·80	3·69	3·40
December	2·81	2·84	2·48
Year ..	55·44	42·66	66·74

At Accra, on the coast, the rainfall in 1893 was 30·38 ins.

RECENT PUBLICATIONS.

Aero-Therapeutics, or the Treatment of Lung Diseases by Climate. By CHARLES THEODORE WILLIAMS, M.A., M.D., F.R.C.P. 8vo. 1894. 187 pp. and plate.

This work comprises the Lumleian Lectures for 1893, which Dr. Williams delivered before the Royal College of Physicians. The object of the author has been to sketch a scientific system of Aero-therapeutics based on the combination of modern meteorology with clinical experience, each element of climate being duly considered in its bearing on health and disease. The first lecture is devoted to the factors and elements of climate; the second lecture is devoted to temperature and moisture; and in the third lecture the author deals with barometric pressure in its relation to health and disease. Dr. Williams also reproduces the address on the climate of Colorado, which he delivered before the Royal Meteorological Society on January 18th, 1893.

American Meteorological Journal. January-June 1894. 8vo.

The January No. contains several papers prepared for the Chicago Congress of Meteorology, viz.—1. History of the Weather Map: by M. W. Harrington (3 pp.). Eighteen current daily Weather Maps are now issued by the various national Weather Services. 2. The Meteorological work of the Medical Department of the U.S. Army: by Major C. Smart (2 pp.). 3. The Meteorological work of the Smithsonian Institution: by the Secretary (2 pp.). 4. Early individual observers in the United States: by A. J. Henry (2 pp.). 5. Storms of the North Atlantic: by E. Hayden (2 pp.). 6. The creation of Meteorological observatories upon the islands scattered over the ocean and connected with a continent by cable: by the Prince of Monaco (2 pp.).—Among the other contributions are:—The recurrence of hurricanes in the solar magnetic 26·68 day period: by Prof. F. H. Bigelow (4 pp.).—A Cloud-burst in Arizona: by J. D. Parker (4 pp.).—Recent foreign studies of Thunderstorms, No. IV.: by R. de C. Ward (9 pp.). The author in this paper gives a summary of the thunderstorm work carried on in Italy since 1882.—Certain climatic features of Maryland: by W. B. Clark (3 pp.).—Ten miles above the earth: by Prof. H. A. Hazen (5 pp.).—Measurement of the seasons: by H. Gawthrop (2 pp. and plate).—The Climate of Louisiana: by R. E. Kerkham (3 pp.).—A new series of isabnormal temperature charts, based on Buchan's isothermal charts: by S. F. Batchelder (24 pp.).—Storms of the Gulf of Mexico and their prediction: by W. D. Stearns (8 pp.).—A new chart of equal annual ranges of temperature: by J. L. S. Connolly (2 pp.).—Meteorology and Geodesy: by Prof. Cleveland Abbe (5 pp.).—The maximum precipitation of south-western North Carolina, particularly on the southern and eastern slopes of the Blue Ridge: by A. J. Henry (4 pp.).—The sea breeze at Boothbay Harbour, Maine: by G. B. Magrath (5 pp.).—The Texan Monsoons: by M. W. Harrington (13 pp.).—The marine Nephoscope and its usefulness to the navigator: by Prof. Cleveland Abbe (10 pp.).—The Pole Star Recorder: by S. P. Fergusson (3 pp.).

Annuaire de la Société Météorologique de France. Tome XLI., July-November 1893. 4to.

The principal articles are:—Sur la prévision du temps et sur l'enchaînement des situations atmosphériques: par P. Garrigou-Lagrange (28 pp. and 2 plates).—Des Nuages et de leur rôle dans la production des hydrométéorites: par C. Ritter (36 pp.). This is an elaborate attempt to explain the formation of clouds, especially of *cumuli*, by means of the phenomena developed when drops of ink or any other coloured fluid are very gently introduced into water. The author gives diagrams showing how the drops bifurcate and bifurcate again and again, giving an appearance like a candelabrum. The paper is divided as follows:—1. Generalities on the natural and mechanical properties of the surface of liquids. 2. The action of the epidermis when capillary veins and sheets of water flow into the air. 3. Action of the dermis when drops, veins, or sheets of certain liquids flow into water mists and liquid clouds. 4. Action of the atmodermes in the escape into the air of smoke and vapour fogs and "pulviscular" clouds. 5, Structure of atmospheric clouds. The author points out that for the produc-

tion of cumulus the existence of a peplum is necessary, a condition of the surface which tends to preserve a definite form. This peplum is absent in the case of stratus. Throughout the paper the author uses the obsolete term of vapeur vésiculaire.

Meteorologische Zeitschrift. Redigirt von Dr. J. Hann und Dr. G. Hellmann. December 1893-May 1894. 4to.

The principal contents are:—Vergleiche von Quecksilber-Barometern mit Siede-Thermometern: von H. Hartl (10 pp.). This is an abstract of a paper published in the *Mittheilungen des K.K. Militär Geographischen Institutes* (see p. 80.).—Ueber die Ermittelung der Temperatur-und Feuchtigkeits-unterschiede zwischen Wald und Feld: von Dr. J. Schubert (7 pp.). This is an account of some interesting experiments carried on by the use of Assmann's apparatus for producing artificial air circulation round the bulbs of thermometers. The desirability of artificial uniform air circulation applied to wet-bulb themometers has long been recognised. Dr. Schubert claims to have shown by his experiments that the alleged difference in temperature and humidity between forest and open ground is solely due to the fact that the air inside the forest is calmer than outside, and that when simultaneous observations are carried on at any pair of twin stations, such as exist in all foreign meteorological systems, by means of Assmann's apparatus, the results are almost identical.—Klimatologische Zeit- und Streitfragen: von Dr. A. Woeikof. No. V. (9 pp.). In this paper the author discusses the regions where continental and oceanic climates are most strongly marked. He endeavours to show that the coldest winters on earth are probably over the Antarctic Continent, and the central portion of Greenland. The warmest summer is probably to be found in the Sahara or the Death Valley of California, and the greatest annual range in Eastern Siberia. One great sign of oceanic climate is the excess of warmth in autumn over spring. In Eastern Siberia, despite its oceanic climate, this relation exists, owing to the fact that snow melting retards the advent of summer in May. The region where spring is decidedly warmer than autumn is in Hindostan. Dr. Woeikof proceeds similarly to discuss relative humidity and precipitation, and concludes with a short notice of the typical oceanic climate of Jan Mayen and Northern Norway.—Ueber die Namen der Winde: von Dr. F. Umlauft (7 pp.). Hesiod only recognised four winds, but by the time of Herodotus the number of points had grown to eight. The names now generally employed are of Germanic origin, and Dr. Umlauft, by deriving their etymology from various languages, seeks to show that East implies clearness, West implies calm, as at sunset, North implies dampness, and so indicates a wind coming from the sea. South is said to be connected with the sun, as in Iceland the South wind is now called 'sunnanvindur.' The man to whom we owe the combination of the cardinal names to indicate intermediate points was Eginhart, in the time of Charlemagne. His windrose had only twelve points, for he left out South south-east, West-south-west, North-north-west and East-north-east. The idea of combination was so practical that it was generally adopted, and completed so as to have sixteen points. Italy has never adopted this nomenclature; there East is Levante, sunrising; West, Ponente, sunsetting. The Sclav wind names are all taken from the course of the sun: the North is midnight; South, midday; East and West, rising and setting respectively.—Die Ergebnisse der schwedischen internationalen Polar-Expedition 1882-83 auf Spitzbergen, Kap Thordsen: von Dr. J. Hann (13 pp.). The author thinks that it has taken a long time to produce this work, but that its value and thoroughness have both been materially improved by the careful consideration which the discussion has received. Dr. Hann gives a summary of the contents of the volume. Among interesting facts it may be mentioned that hail was never once observed. The winter in Spitzbergen was the mildest experienced by any of the expeditions except that of the Austrians in Jan Mayen. The extremest cold in winter was reported by the Russians at the mouth of the Lena, the coldest summer by the Dutchmen in the Kara Sea. As regards the wind, the Swedes report that in winter the velocity was a maximum at night and a minimum in the forenoon. In summer this is reversed. The paper concludes with a list of the volumes in the *Zeitschrift* in which notices of all the Polar Expeditions are to be found, with their respective authors' names.—Neue Normaltemperaturen; von Dr. W Precht (10 pp.). This paper deals with the construction of

isabnormal curves of temperature similar to those of Batchelder in the *American Meteorological Journal*, Vol. X. Dr. Precht refers to Spitaler's paper on temperature anomalies in *Petermann's Mittheilungen* for 1887, which, however, has only one chart for the year. Dr. Precht's own charts are not given in the *Zeitschrift*. The temperature charts on which they are based are Hann's in Berghaus' *Physical Atlas*. At the end of the paper the author takes up Angot's "Recherches origines sur la distribution de la chaleur à la surface du globe" from the *Annales du Bureau Central Météorologique de France* for 1893, which enable him to calculate normal temperatures by a different process, and the results agree very satisfactorily with those previously obtained by him.—N. Ekholm's Untersuchungen über das Verhalten des Psychrometers unter dem Gefrierpunkt: von J. Hann (9 pp.). This is a paper criticising the results given in the last volume of meteorological data of the Swedish expedition to Spitzbergen in 1882-3. Dr. Ekholm instituted a most careful investigation into the anomalous behaviour of the wet bulb, and finds that when the results are calculated by the usual formulæ for low temperatures the indications are considerably too high. He says that if the hygrometer is in good order, very good results for both vapour tension and relative humidity can be obtained down to very low temperatures if a constant correction of —0°·45 C, or 0°·81 F, is applied. The explanation given of this is that vapour of low tension is disseminated through the atmosphere with extreme slowness, consequently the tension of the vapour a few inches above a snow or ice surface is much higher than that in immediate contact with the snow, etc. The idea is that the thermometer bulb is brought into this surcharged stratum, vapour from that stratum condenses on the bulb and the latent heat raises the temperature of the bulb.—Die Vertheilung des Luftdruckes über Europa während der Trockenzeiten des Frühlings und Sommers 1893: von Dr. E. Less (16 pp. and plate). This is a discussion of the causes of the abnormal summer of 1893, a subject which has been frequently attacked. Dr. Less thinks that he has found the cause of the extraordinary persistence of the anticyclones in the fact that very unusual cold with an intense anticyclone prevailed over northern Russia throughout the spring and early summer.—Ueber die Einwirkung der ablenkenden Kraft der Erdrotation auf die Luftbewegung: von Dr. N. Ekholm (27 pp). This is a mathematical investigation into the action of the rotation of the earth on wind motion.—Die Resultate der meteorologischen Beobachtungen auf dem Pic du Midi: von Dr. F. Klengel (20 pp). This is an elaborate discussion of the work done on the Pic du Midi.

Meteorology, The Elements of Weather and Climate. By H. N. Dickson, F.R.S.E. 8vo. 1893. 192 pp.

This work forms one of the University Extension Series, and contains, in fact, the substance of a course of Lectures on Meteorology, delivered by Mr. Dickson as a University Extension Lecturer. The author deals with the subject in a clear and simple manner. The work is divided into 8 chapters, viz. fundamental facts; fundamental principles; cyclones; anticyclones; other forms of pressure areas; weather forecasting; meteorological instruments and observations; the elements of climate; and application of meteorology to agriculture.

Report of the Chief of the Weather Bureau, 1891-92. U.S. Department of Agriculture. 4to. 1893. 528 pp. and 4 plates.

This is the first volume of meteorological data published by the Weather Bureau, and contains the results of observations made during 1891 and 1892. Prof. C. F. Marvin contributes a description with illustrations of the instruments in use at the principal stations of the Weather Bureau; and Prof. Cleveland Abbe has a paper on instrumental corrections, methods of reduction, and resulting accuracy.

Symons's Monthly Meteorological Magazine. Vol. XXIX. Nos. 337-341. February-June, 1894. 8vo.

The principal articles are:—The January Frost (7 pp.).—A wet February in Edinburgh (1 p.).—Sun spots and air temperature (4 pp.).—The climate of Odessa (2 pp.).—Iridescence on the English Lakes (3 pp.).—The May Frost of 1894 (8 pp.).

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ON THE RELATIVE FREQUENCY OF DIFFERENT VELOCITIES OF WIND.

BY WILLIAM ELLIS, F.R.S.

(Plate IV.)

[Received April 10th.—Read May 16th, 1894.]

HAVING had occasion a few months ago to prepare some statistics in regard to wind velocity, I have since carried the inquiry somewhat further with the view of rendering the results more complete, and, with the permission of the Astronomer Royal, now beg to submit them to the notice of the Royal Meteorological Society.

The object of the paper has been to ascertain the number of hours during which the wind blew with each of the different hourly velocities experienced during the period under discussion. Such information may have a value, in view of the use of wind engines for pumping and other purposes, as affording some indication of the amount of work that may be expected from an

engine constructed to act with a certain velocity of wind, as measured by a Robinson anemometer as usually constructed. The question being one on which I have more than once been asked to supply information, the results may be presumed to possess some general interest.

The discussion was confined to the five years 1888 to 1892, the record of the Robinson anemometer of the Royal Observatory, Greenwich (giving horizontal velocity), being employed. In tabulating from the records, the hourly velocity is entered to the nearest mile. On each day through the period mentioned the number of hours for each of the several velocities recorded was counted, placing in the first column the number of hours (if any) for which the tabulated value was either 0 or 1 mile; in the following column the number of hours of tabulated values of either 2 or 3 miles; and so on. The combination of the five months of January gave 155 days, or 3720 hours. February gave in all 142 days, or 3408 hours; March 3720 hours, and so on. In April and May there was a deficiency caused by the loss of record for nine days at the end of April, and eight days at the beginning of May, of the year 1889. In all other months the full number of days is available. The results (monthly sums of hours at different velocities) are given in Table I., the mean daily velocity for each month, on the mean of the five years, being also added. No regard has been paid to direction of wind.

The number of hours being necessarily different in different months, the monthly sums were not strictly comparable. To make them so they were proportionately altered where necessary, so as to correspond to monthly periods of 30 days, giving for each month of the year, in all 150 days, or 3600 hours. These corrected results will be found in Table II., the quarterly and yearly sums being also exhibited graphically in the diagram (Plate IV.).

In each quarter of the year (see Table II.) the wind blew for the greatest number of hours with the hourly velocities of 10 or 11 miles, and this was the case also in each separate month, excepting those of September and December. In autumn and winter nearly as many hours were registered at velocities considerably lower, but in spring and summer the numbers of hours at the corresponding lower velocities were distinctly less than at the velocities of 10 and 11 miles. With velocities greater than 11 miles, the number of hours very rapidly falls off, in all months of the year.

Comparing spring and winter taken together with summer and autumn taken together it is seen, neglecting velocities below 4 miles, that from velocities 4-5 miles to velocities 12-13 miles the wind blew for a greater number of hours in summer and autumn than in spring and winter, but that for velocities above 13 miles this is reversed, the number of hours in spring and winter being the greater, the difference increasing rapidly with increase of velocity. On consideration it will be understood that this is a result that might be expected. Summer and autumn are not seasons of heavy gales, so that the number of hours registered at moderate velocities will necessarily be greater than in spring and winter. On the other hand, the gales of spring and winter cause a greater number of hours of higher velocities to be then registered than in summer and autumn.

TABLE I.—NUMBER OF HOURS DURING WHICH THE WIND BLEW WITH DIFFERENT HOURLY VELOCITIES IN THE YEARS 1888 TO 1892, AS REGISTERED BY THE ROBINSON ANEMOMETER (THE BROWNING INSTRUMENT) AT THE ROYAL OBSERVATORY, GREENWICH.

(As actually recorded.)

Month.	Mean Daily Velocity.	Total Number of Hours.	Hourly Velocity of Wind in Miles.																												
			0–1.	2–3.	4–5.	6–7.	8–9.	10–11.	12–13.	14–15.	16–17.	18–19.	20–21.	22–23.	24–25.	26–27.	28–29.	30–31.	32–33.	34–35.	36–37.	38–39.	40–41.	42–43.	44–45.	46–47.	48–49.	50–51.	52–53.	54–55.
	Miles.		Number of Hours.																												
January	300	3720	150	234	327	386	406	435	336	358	266	192	136	131	80	64	67	45	26	22	20	16	9	7	4	2	1	..	..	..
February	294	3408	172	197	270	322	334	452	291	366	273	193	158	117	84	56	33	28	18	26	7	6	5	..	..	..	..	..	..	..
March ..	334	3720	70	122	248	346	405	485	321	346	254	257	257	144	154	109	77	53	23	18	8	6	7	1	..	1	6	2	..	..
April	274	3384	70	173	361	388	390	523	353	332	223	179	150	90	78	33	20	15	5	..	1	..	..	..	..	..	..	..	..	..
May	258	3528	102	232	363	453	494	514	335	334	222	136	129	69	45	30	18	14	12	13	4	7	1	1	..	..	..	..	..	..
June	237	3600	145	229	382	501	533	571	400	310	219	138	102	37	24	8	1	..	..	..	..	..	..	..	..	..	..	..	..	..
July	258	3720	96	212	318	443	548	648	441	369	224	148	112	56	37	28	19	16	4	1	..	..	..	..	..	..	..	..	..	..
August ..	266	3720	80	158	355	534	519	572	391	346	268	154	125	76	51	32	24	20	7	4	3	1	..	..	..	..	..	..	..	..
September	232	3600	138	308	426	552	517	521	314	264	195	170	82	40	33	16	14	4	5	1	..	..	..	..	..	..	..	..	..	..
October ..	266	3720	121	242	407	483	477	533	303	287	255	186	168	78	57	37	41	16	3	11	7	2	4	1	1	..	..	..	..	..
November	273	3600	145	341	414	376	409	456	326	261	203	163	135	89	60	45	43	40	33	18	18	16	4	1	1	1	..	..	1	1
December	260	3720	233	413	487	402	355	372	305	263	206	166	145	93	82	69	32	24	12	13	14	8	4	5	3	6	3	4	..	1

TABLE II.—Number of Hours during which the Wind blew with different Hourly Velocities in the Years 1888 to 1892, as registered by the Robinson Anemometer (the Browning Instrument) at the Royal Observatory, Greenwich.

(Reduced to months of 30 days, giving in the five years 3600 hours in each month.)

Month.	Hourly Velocity of Wind in Miles.																											
	0–1.	2–3.	4–5.	6–7.	8–9.	10–11.	12–13.	14–15.	16–17.	18–19.	20–21.	22–23.	24–25.	26–27.	28–29.	30–31.	32–33.	34–35.	36–37.	38–39.	40–41.	42–43.	44–45.	46–47.	48–49.	50–51.	52–53.	54–55.
	Number of Hours.																											
January....	145	226	316	374	393	421	325	347	257	186	132	127	77	62	65	44	25	21	19	15	9	7	4	2	1	..	..	..
February ..	182	208	285	340	353	478	307	387	288	204	167	124	89	59	35	30	19	27	7	6	5	..	..	..	..	..	..	..
March	67	118	240	335	392	469	311	335	246	249	249	139	149	105	75	51	22	17	8	6	7	1	..	1	6	2	..	..
April	75	184	384	413	415	556	376	353	237	190	160	96	83	35	21	16	5	..	1	..	..	..	..	..	..	..	..	..
May	104	237	370	462	504	524	342	341	227	139	132	71	46	31	18	14	12	13	4	7	1	1	..	..	..	..	..	..
June	145	229	382	501	533	571	400	310	219	138	102	37	24	8	1	..	..	..	..	..	..	..	..	..	..	..	..	..
July	93	205	308	429	530	627	427	357	217	143	109	54	36	27	18	15	4	1	..	..	..	..	..	..	..	..	..	..
August	77	153	344	517	502	554	378	335	259	149	121	74	49	31	23	19	7	4	3	1	..	..	..	..	..	..	..	..
September	138	308	426	552	517	521	314	264	195	170	82	40	33	16	14	4	5	1	..	..	..	..	..	..	..	..	..	..
October	117	234	394	467	462	516	293	278	247	180	162	75	55	36	40	15	3	11	7	2	4	1	1	..	..	..	..	..
November	145	341	414	376	409	456	326	261	203	163	135	89	60	45	43	40	33	18	18	16	4	1	1	1	..	..	1	1
December ..	225	400	471	389	343	360	295	254	199	161	140	90	79	67	31	23	12	13	14	8	4	5	3	6	3	4	..	1
Spring	324	510	909	1088	1160	1503	994	1075	771	643	576	359	321	199	131	97	46	44	16	12	12	1	..	1	6	2	..	..
Summer ..	342	671	1060	1392	1567	1722	1169	1008	663	420	343	162	106	66	37	29	16	14	4	7	1	1	..	..	..	..	..	..
Autumn ..	332	695	1164	1536	1481	1591	985	877	701	499	365	189	137	83	77	38	15	16	10	3	4	1	1	..	..	..	..	..
Winter	515	967	1201	1139	1145	1237	946	862	659	510	407	306	216	174	139	107	70	52	51	39	17	13	8	9	4	4	1	2
Spring and Winter	839	1477	2110	2227	2305	2740	1940	1937	1430	1153	983	665	537	373	270	204	116	96	67	51	29	14	8	10	10	6	1	2
Summer and Autumn	674	1366	2224	2928	3048	3313	2154	1885	1364	919	708	351	243	149	114	67	31	30	14	10	5	2	1	..	..	..	..	..
The Year ..	1513	2843	4334	5155	5353	6053	4094	3822	2794	2072	1691	1016	780	522	384	271	147	126	81	61	34	16	9	10	10	6	1	2

February, March, April = Spring; May, June, July = Summer; August, September, October = Autumn; November, December, January = Winter.

Comparing together the values in any one of the vertical columns of Table II., we get an idea of the relative frequency of a given velocity of wind in different months of the year, that is an indication of the months in which the greatest number of hours for any particular velocity may be expected to occur. There is a certain irregularity in the values in the months of March and December, due to the mean velocity in these months (first column of Table I.) being, in March especially high, and in December remarkably low, an irregularity that, if a longer series of years had been employed, might have disappeared. Making some allowance for this, the numbers of Table II. may be seen to indicate generally the manner of distribution of wind velocity in different parts of the year. But considerable variation may be expected to occur in the same month in different years, as is indeed the case with the results for the separate years 1888 to 1892, which, having regard to economy of space, it was not thought necessary to give in detail.

The wind velocities here discussed depend on results deduced by use of the factor 8 (relation of movement of cups to velocity of wind). The effect of substituting a variable factor more nearly in accord with experiment (as kindly made by Mr. Dines) would be (see the diagram) to make the ascent to the maximum more steep, and the descent after the maximum more rapid, without really displacing the position of maximum (for which particular velocity the factor 8 as nearly as possible agrees), or indeed affecting the general relations of things indicated by the results as presented.

The revolving cups of the anemometer are 56 feet above the adjacent ground, and 211 feet above mean sea-level.

Addendum, June 20th, 1894.

On the occasion on which my paper "On the Relative Frequency of different Velocities of Wind" was read before the Society, a wish was expressed that I should add a table giving the corresponding hourly velocity of the wind at different hours of the day. I stated that this had not been done because the individual volumes of *Greenwich Observations* contained such information for each particular year. But it has since appeared to me that there would be convenience in adding this related information, and what I have done is to collect the results for the five years 1888 to 1892, as appearing in the separate Greenwich volumes, and combine them to form a table of mean values for the whole period (p. 242), thus providing results which are comparable with those given in the paper.

MEAN HOURLY VELOCITY OF THE WIND, IN MILES, ON THE AVERAGE OF THE YEARS 1888 TO 1892, AS REGISTERED BY THE ROBINSON ANEMOMETER (THE BROWNING INSTRUMENT) AT THE ROYAL OBSERVATORY, GREENWICH.

Month.	Hour Ending.																								Mean.
	1 h.	2 h.	3 h.	4 h.	5 h.	6 h.	7 h.	8 h.	9 h.	10 h.	11 h.	Noon.	13 h.	14 h.	15 h.	16 h.	17 h.	18 h.	19 h.	20 h.	21 h.	22 h.	23 h.	Midnight.	
	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.	m.
January	11·7	11·6	11·7	11·6	11·8	12·0	11·9	11·9	11·6	12·0	12·6	12·9	14·3	14·6	14·0	13·4	12·9	12·8	13·0	12·9	12·4	12·5	12·2	11·9	12·5
February	11·3	11·2	11·1	11·2	11·1	11·0	10·9	10·9	11·5	12·2	13·0	13·7	14·3	14·5	14·2	13·9	13·2	12·7	12·6	12·4	12·1	11·9	11·8	11·5	12·3
March	12·9	12·6	12·4	12·6	12·1	12·4	12·5	12·6	13·9	15·0	15·7	15·8	16·6	16·4	16·3	16·0	15·6	14·9	13·6	13·2	13·2	12·9	12·7	12·3	13·9
April	9·5	9·2	9·0	8·9	8·7	9·2	9·6	10·1	11·4	12·2	13·0	13·1	13·6	14·5	14·9	14·9	14·3	13·8	12·7	11·0	10·7	10·4	10·0	9·6	11·4
May	9·0	8·8	8·4	8·3	8·3	8·5	9·0	10·0	10·5	11·4	12·5	12·7	13·4	13·8	13·7	13·6	13·3	12·7	11·8	10·4	9·8	9·7	9·4	8·8	10·7
June	8·2	8·1	7·7	7·6	7·7	7·6	8·3	9·1	9·8	10·5	10·8	11·2	11·6	12·4	12·4	12·7	12·3	12·0	11·4	10·4	9·2	8·7	8·7	8·4	9·9
July	9·3	9·0	8·7	8·8	8·7	9·1	9·5	10·1	10·8	11·7	11·8	12·3	12·4	13·2	13·3	13·0	12·9	12·1	11·6	10·8	10·1	9·8	9·6	9·2	10·7
August	9·5	9·1	8·8	8·8	8·7	8·7	9·0	10·0	11·1	11·9	12·7	12·9	13·5	13·9	14·0	13·9	13·6	12·6	11·7	11·1	10·7	10·1	10·1	9·5	11·1
September	8·2	7·7	7·7	7·9	8·0	7·9	7·9	8·5	9·3	10·6	11·4	11·9	12·1	12·6	12·4	12·0	11·4	10·3	9·9	9·5	9·1	8·9	8·7	8·1	9·7
October	10·0	10·1	10·0	10·2	10·0	10·0	9·8	10·0	10·1	11·2	12·2	12·8	13·6	13·5	13·2	12·7	11·6	11·0	10·8	10·6	10·8	10·5	10·6	10·3	11·1
November	10·9	10·9	10·9	10·7	10·3	10·5	10·5	10·5	10·4	11·1	11·5	11·8	12·7	13·2	12·8	12·1	11·8	11·3	11·7	11·8	11·5	11·6	11·2	10·9	11·3
December	10·3	10·3	10·1	10·1	10·4	10·2	10·2	10·3	10·3	10·7	11·2	11·3	12·2	12·3	11·6	11·0	11·0	11·0	11·0	11·2	11·1	10·8	10·7	10·7	10·8
The Year	10·1	9·9	9·7	9·7	9·6	9·8	9·9	10·3	10·9	11·7	12·4	12·7	13·4	13·7	13·6	13·3	12·8	12·3	11·8	11·3	10·9	10·7	10·5	10·1	11·3

According to the experiments made by Mr. Dines, see *Greenwich Magnetical and Meteorological Observations 1889*, page lxiii., the hourly velocity registered by the Browning Instrument, for which the factor 3 exactly applies, is 11·7 miles, almost precisely the mean value of the above table.

DISCUSSION.

Admiral J. P. MACLEAR said that it would be interesting to compare the results from the Greenwich wind records with observations of wind force at sea. The average rate of a sailing vessel was 120 miles a day, or about 5 knots an hour, a rate of travel which would require a wind force closely approximating the most frequent hourly velocity at Greenwich.

Mr. C. HARDING inquired whether any correction for friction had been applied to the observations, because he thought that probably friction might be the cause of some of the irregularities shown in the figures for hourly velocities of 12 to 18 miles. But, as Mr. Ellis had said, five years' results, though valuable, could not be regarded as affording trustworthy data, particularly, too, as the period discussed appeared to have been a more than usually calm series of years. It would be an interesting addition to the paper if the mean hourly velocities were given.

Mr. W. ELLIS, in reply, said that no correction had been applied to the figures, the tabulations having been made direct from the anemometrical records. Nothing had been said in the paper about hourly velocities, because the mean hourly velocities for each month in the year were given annually in the Greenwich volumes.

AUDIBILITY OF "BIG BEN" AT WEST NORWOOD UNDER CERTAIN METEOROLOGICAL CONDITIONS.

By WILLIAM MARRIOTT, F.R.Met.Soc.

[Read May 16th, 1894.]

In the year 1882, when preparing, in conjunction with the Hon. Ralph Abercromby, a paper on "Popular Weather Prognostics," I found that there was a lack of observations on the travel of sound—or audibility—in relation to meteorological conditions. As I could occasionally hear in my garden at West Norwood "Big Ben" of Westminster striking the hours, I decided upon recording in my note book whether I could hear the bell at the usual hours of observation, viz. 9 a.m. and 9 p.m. My garden, which was about 180 feet above sea level, was on ground sloping to the north, and was perfectly open in that direction. The Clock Tower at Westminster could be seen from the upper part of the house, and was distant about five miles and a half in a north by west direction.

The Clock Tower is situated at the northern end of the Houses of Parliament, and closely abuts on Westminster Bridge. The tower, which is 40 feet square, is surmounted by a richly decorated belfry and spire rising to the height of about 320 feet. The clock has four dials, which are 22½ feet in diameter. The minute spaces are a foot square, and the figures 2 feet long. The dials and hands cost £5,334, or more than the clock and the bells together.

The large bell, "Big Ben," weighs about 14 tons, and is 9 feet 5½ inches in diameter and 9¾ inches in thickness. On one side of its waist is cast a representation of the portcullis of Westminster, and on the other side the

arms of England. Round the outer lip is cast in Gothic letters: "This bell was cast by George Mears, of Whitechapel, for the clock of the Houses of Parliament, under the direction of Edmund Beckett Denison, Q.C., in the 21st year of the reign of Queen Victoria, and in the year of our Lord MDCCCLVIII."

The tone of the bell is E. The hammer weighs 4 cwt., and is lifted 18 inches from the bell, or about 9 inches vertically. The gearing is so arranged that the hammer falls exactly when the clock reaches the 60th second of the last minute of the hour; while at the 1st, 2nd, and 3rd quarters of the hour the first bell of the chimes is struck at those times respectively, the 4th quarter being let off about 20 seconds before the hour so that it may have done chiming before the hour begins at the real time.

The observations extended from October 1882 to November 1887, and were made as frequently as I could be sure that I was within range of hearing the bell at the *precise* time of striking. As the bell could at times be heard more distinctly than at others, I adopted the following scale, viz.:—

0 = when "Big Ben" could not be heard at all
1 = " " " be heard faintly
2 = " " " " distinctly
3 = " " " " very distinctly

There were in all 976 observations, which were distributed as follows:—

	9 A.M.		9 P.M.	
	No. of Obs.	per cent.	No. of Obs.	per cent.
"Big Ben" not heard	251	76·8	431	66·4
" " heard faintly	64	19·6	160	24·7
" " " distinctly... ...	8	2·4	51	7·9
" " " very distinctly ...	4	1·2	7	1·0

It will thus be seen that "Big Ben" could be heard more frequently in the evening than in the morning. This may possibly be due to there being less *noise*—such as that caused by trains, vehicles, machinery, &c.—in the evening than in the morning. With the view of testing this point still further, I extracted all Sunday observations, the results of which show that the bell can be heard to much greater advantage on Sundays than on week days:

Sunday observations	9 A.M.		9 P.M.	
	No. of Obs.	per cent.	No. of Obs.	per cent.
"Big Ben" not heard	86	72·9	78	60·0
" " heard faintly	22	19·5	34	26·2
" " " distinctly	5	4·3	15	11·5
" " " very distinctly ...	4	3·3	3	2·3

The results of the observations are shown graphically in the accompanying diagrams, in which the thick lines represent the percentage of audibility on the number of observations given in figures at the bottom of each line.

Wind.—"Big Ben" was most frequently heard with winds from West to North, and less frequently with winds from South to East. (Fig. 1.)

The percentage of audibility was greatest on Sunday evenings, "Big Ben" being heard with all winds, but most frequently, as before, from West to North. (Fig. 2.)

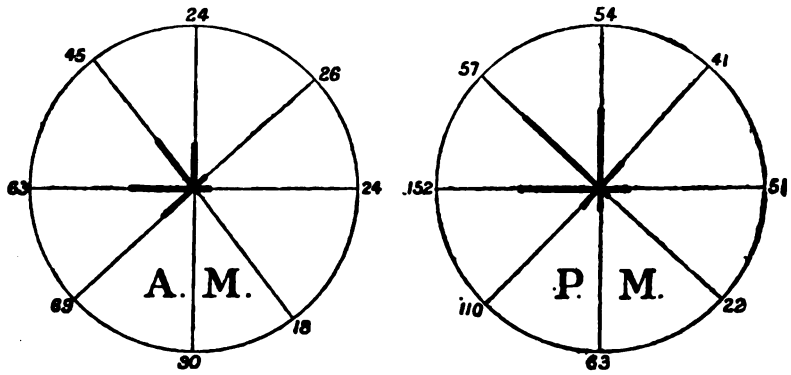


FIG. 1.—Audibility of "Big Ben" with different Winds. The thick lines show the percentage of audibility and the figures at the extremity of the radii the number of observations.

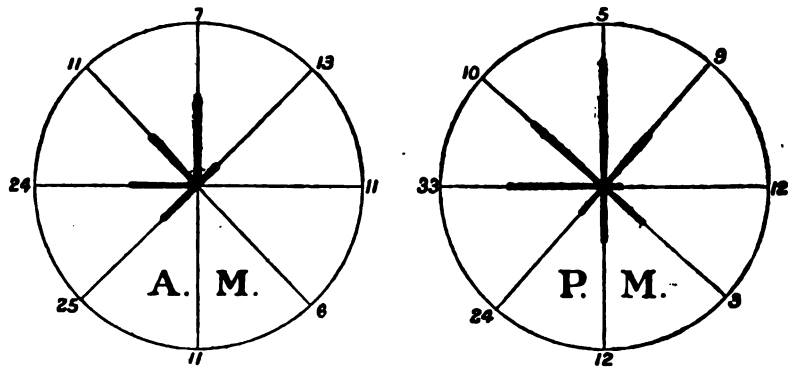


FIG. 2.—Audibility of "Big Ben" with different Winds. Sunday Observations only.

Barometer.—From the morning observations it appears that the percentage of audibility was greater with the low and the high readings of the barometer than with the intermediate readings. A somewhat similar grouping appears in the evening observations, although the differences in the percentages are not so marked as in the morning observations. (Fig. 3.)

From an examination of the *Daily Weather Charts* for a number of days on which "Big Ben" was heard, it appears that the conditions most favourable for audibility are when a cyclonic disturbance is to the eastward of London or when an anticyclonic area is in the neighbourhood. Under some such circumstances there is a tendency for the wind to blow as a downward current, and so probably to carry the sound for a greater distance along the surface of the earth, than when other conditions prevail, as when the wind

has an upward tendency and will carry the sound rather in an upward direction than along the surface of the ground.

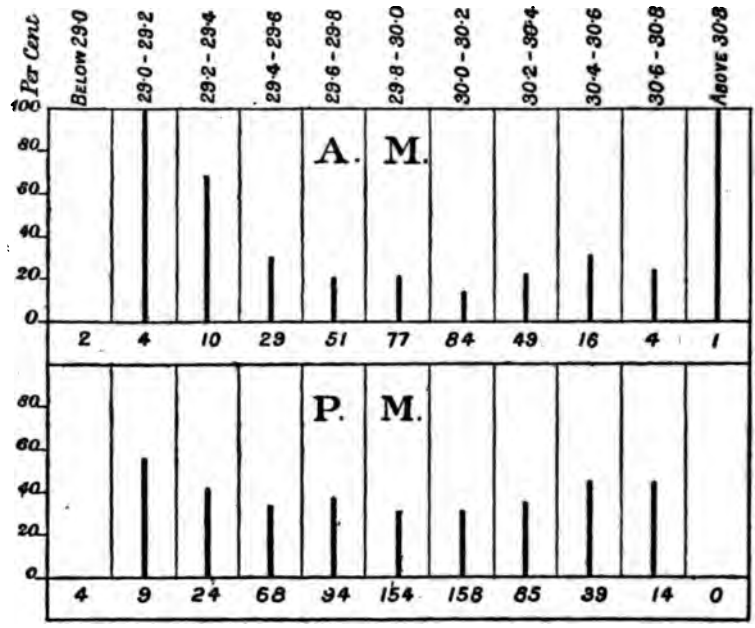


FIG. 3.—Audibility of "Big Ben" with different heights of the Barometer. The thick lines show the percentage of audibility, and the figures below the number of observations.

On two occasions the quarter chimes were also heard. These were: (1) on Sunday, October 17th, 1886, at 9 p.m., when we were in the rear of a slow moving depression; and (2) on Wednesday, March 30th, 1887, at 9.30 p.m., when we were on the eastern side of an anticyclone.

Temperature.—In the morning the percentage of audibility appears to be greater with low temperatures than with high temperatures. As possibly the low temperatures occurred with radiation weather, there might be a downward current which would be favourable for audibility; while with the higher temperatures there would probably be an ascending current, which would be unfavourable for audibility.

The percentages of audibility are much more uniform in the evening, when probably the air has mostly a downward tendency. (Fig. 4.)

Cloud.—The percentage of audibility in the morning appears to be greater with clear skies than with cloudy ones, while in the evening the opposite occurs. (Fig. 5.)

A curious point brought out by these observations is that the sky was most frequently overcast at 9 a.m., and that at 9 p.m. it was either clear or overcast, the intermediate amounts of cloud being very small.

Difference between Dry and Wet Thermometers.—The percentage of

audibility appears in the morning to be greatest when the difference between the dry and wet bulb thermometers was from 1° to 8°; while in the evening the percentages are much more uniform. (Fig. 6.)

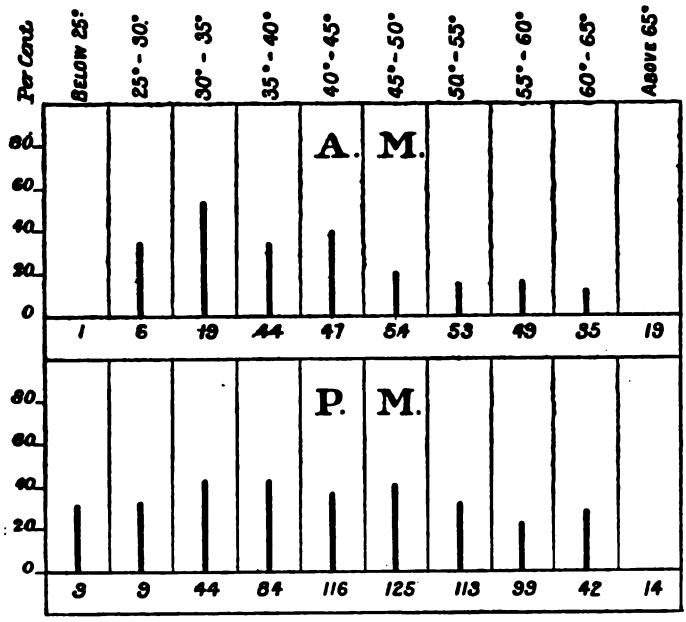


Fig. 4.—Audibility of "Big Ben" with different Temperatures.

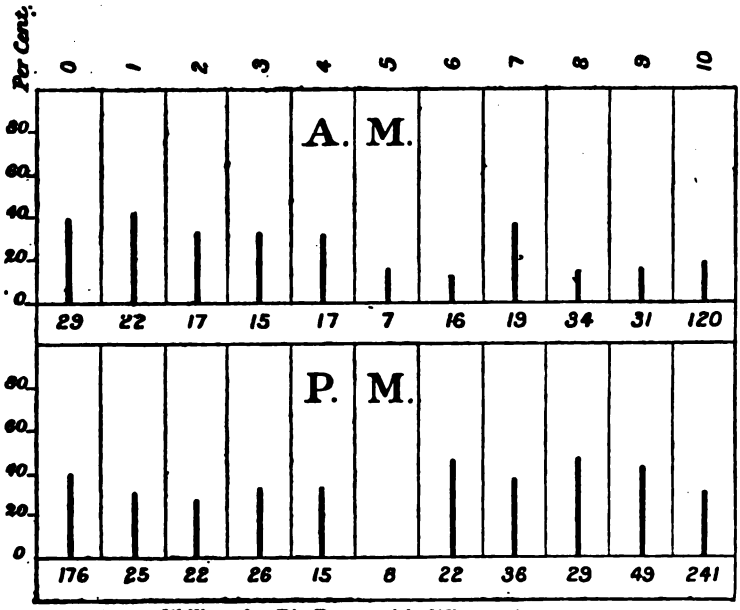


Fig. 5.—Audibility of "Big Ben" with different Amounts of Cloud.

Dr. Tyndall, on January 16th, 1874, at the Royal Institution, gave a lecture "On the Acoustic Transparency and Opacity of the Atmosphere," which embraced the scientific results of an inquiry on fog signals, undertaken at the instance of the Elder Brethren of the Trinity House. In con-

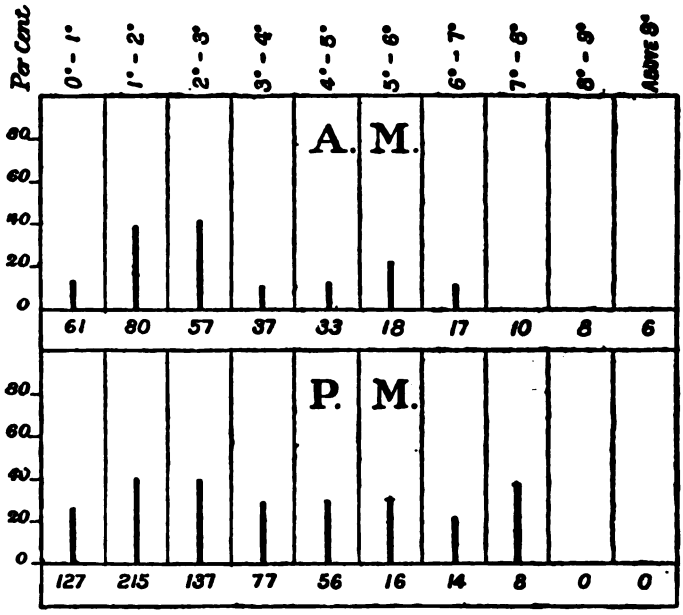


FIG. 6.—Audibility of "Big Ben" with differences between the Dry and Wet Thermometers.

cluding the lecture he said: "The real enemy to the transmission of sound through the atmosphere has, I think, been clearly revealed by the foregoing inquiry. That enemy has been proved to be not rain, nor hail, nor haze nor fog, nor snow—not water, in fact, in either a liquid or a solid form—but water in a vaporous form, mingled with air so as to render it acoustically turbid and flocculent. This acoustic turbidity often occurs on days of surprising optical transparency. Any system of measures, therefore, founded on the assumption that the optic and acoustic transparency of the atmosphere go hand in hand must prove delusive."[1]

DISCUSSION.

THE PRESIDENT (Mr. R. Inwards) said that it was interesting to find that there was a fair degree of agreement between the amount of cloud and the audibility of "Big Ben." It would be interesting if the height and form of cloud could be considered in this connection, as it was conceivable that a sheet of stratus cloud would be more effectual in reflecting the sound earthwards than would clouds of irregular form.

[1] *Proceedings of the Royal Institution.* Vol. VII. p. 178.

Mr. F. GASTER said that his residence in Acre Lane, Brixton, was about 3 miles due south of "Big Ben," but he was sure that he heard the clock bell more frequently with Westerly than with Northerly winds. This curious state of things was to be partly accounted for by the fact that Westerly winds were the winds of greatest frequency, but there was one condition of pressure distribution which also assisted in producing this effect. When a depression had passed over London, and pressure became highest in the south, the wind frequently was West-south-west at the earth's surface, while at a comparatively short distance above the earth it blew from a North-westerly direction, and it was this upper current which conveyed the sound.

Capt. D. WILSON-BARKER alluded to some experiments which had been carried out in American waters, in which a distinction had been drawn between reflected sounds and sounds which came direct. The manner in which sounds were heard at sea was most curious, and a small sail on a vessel had been known to reflect the sound of a whistle in an altogether astonishing manner.

Mr. R. H. SCOTT drew attention to the reports published by Professor Mohn in the *Annalen der Hydrographie* for 1892 and 1893 of his inquiries into fog signals. These were conducted at the Island of Färder, in the Christiania Fjord, as complaints of the frequent inaudibility of the Färder siren had reached Christiania. The island is isolated, so that the sound could be tested in all directions. An abstract of results given in the first report will be found in the *Quarterly Journal*, Vol. XIX. p. 61. The chief fact is that sounds are heard best to leeward, and better across the wind than to windward. They travel better in warm than in cold weather, but under all circumstances there are great variations, as yet unexplained, in the audibility of sounds. They are heard better at the mast head than on deck, evidently because the sound waves are reflected from horizontal strata of air. The second report deals with an attempt to account for the variability of the distance at which the sound can be heard.

Mr. G. J. SYMONS said that when he first went to reside in Camden Town (which was north of Westminster) in 1857, he was accustomed to hear "Big Ben" twice or thrice a week; but now, owing probably to the increase in buildings, &c., the bell was rarely heard more than once in three weeks or so. The audibility of "Big Ben" was regarded at his house as an infallible sign of wet weather. It was rarely heard except with wind at South-south-east to South-south-west, and rarely except at night, when the traffic in town was less.

Mr. R. H. CURTIS said it appeared to him that the paper merely showed the relative frequency of Northerly winds at Mr. Marriott's residence, and all the phenomena mentioned were such as one would expect to find with such winds. The wind diagrams showed that the sound was only heard when the wind was Northerly or North-westerly, and with such winds there would of course be either a low pressure area to the eastward or an anticyclone to the westward, as Mr. Marriott said was the case; in the former cases, the depression having passed away to the eastward, the sky would have cleared and the amount of cloud would be small, while in the latter the sky would generally be overcast, and thus there would be the two extremes of cloudiness mentioned; and in both cases one would expect a low, or relatively low, temperature.

Admiral J. P. MACLEAR remarked that the difference in the audibility of the voices of ships' officers in stormy weather at sea was very remarkable, and strong-voiced men who shouted their orders could only be heard at a short distance, while weaker voices, but of a reedy quality, were audible for the whole length of the ship. He (Admiral Maclear), when a lieutenant, had to make his voice heard throughout three decks, and he found that the best way to accomplish this was to intone the orders.

Mr. W. ELLIS said that he also had not unfrequently heard "Big Ben" at Greenwich, which was about the same distance from Westminster as West Norwood. That it was really "Big Ben" that was heard was known by noting the interval between the successive strokes in striking the hour.

Mr. C. HARDING said that he resided at Brixton, on the south side of "Big Ben," and always regarded the audibility of the bell as indicative of fine weather. Concerning the question of inversion of temperature, Mr. Glaisher in his balloon ascents had found at evening time an increase of temperature with elevation above the earth's surface, extending to a height of 2,000 feet.

Dr. A. BUCHAN said that the audibility of sound depended upon the homo-

geneity of the atmosphere, and vertical air currents would disturb this condition. In the summer there would be ascending currents with a warm temperature in the morning, and descending currents with a cooler atmosphere at night, consequently the hours of 9 a.m. and 9 p.m. were rather unfavourable to the distinct transmission of sound. A more suitable hour of observation would be about 4 p.m. In the rear of cyclones, when North-westerly winds prevailed, the atmosphere was most homogeneous, as the temperature was even and the wind current deep and strong. The difference between the audibility in the morning and evening was doubtless due to the difference in the noise in London at the hours of observation as well as of atmospheric conditions.

Mr. W. MARRIOTT, in reply, said that his observations of the audibility of "Big Ben" had been brought to an end, owing to his removal to a house situated on the south-east slope of a hill where "Big Ben" was very rarely heard, although the distance between this and the former place of observation was only a quarter of a mile. The observations discussed in the paper were fairly distributed over the year. The effect of the inversion of temperature on the transmission of sound was an interesting question, and it would be a good thing if a set of meteorological observations were made at the top of the Westminster Clock Tower.

EARTH TEMPERATURES AT CRONKBOURNE, ISLE OF MAN, 1880-89.

By A. W. MOORE, M.A.

[Received April 27th.—Read May 16th, 1894.]

THE following are the results of 10 years' observations, at 9 a.m.,[1] of the temperatures recorded by thermometers placed respectively at 1, 2, 3, and 4 feet below the level of the ground (Table I.), as compared with the shade temperature at 4 feet above it, taken at 9 a.m. and 9 p.m. and 9 a.m. only, and with the daily minimum on the grass. Generally speaking, the results are very much what might have been expected *a priori*, but still the variations of temperature are curious and interesting. The highest annual mean, 48°·5, has been recorded at 4 feet below the ground; 3 feet being next, with 48°·4; 2 feet, with 48°·3; 1 foot, with 47°·8; while the mean shade temperature at 9 a.m. and 9 p.m. for the same period was 47°·9, and at 9 a.m. only, 49°·0. It will be noticed that all these underground temperatures, except that at 1 foot, are above the mean annual temperature, taken at 9 a.m. and 9 p.m., at 4 feet above the ground, but this may be partly accounted for by the underground thermometers being momentarily exposed to the air[2] at 9 a.m., when the temperature is higher than the mean between 9 a.m. and 9 p.m.; also that the variation of temperature between the different levels is not similar, that between 1 and 2 feet being 0°·5, between 2 and 3 feet, 0°·1, and between 3 and 4 feet, 0°·1.

[1] The thermometers are fastened to a wooden lath enclosed in a round iron tube.

[2] The thermometers were pulled up, read, and pulled down in about 15 seconds, but it should be noted that the 1 foot thermometer would be exposed a slightly longer time to the influence of the outside temperature than the one at 2 feet, and so on.

The next point we may note is that, while the thermometer at 1 foot below the ground attains its maximum of 57°·2 in July, and its minimum of 40°·5 in January, corresponding with the shade temperature[1] of 56°·9, and of 40°·8 in the same months; the thermometer at 2 feet attains its maximum of 56°·6 in August, and its minimum of 41°·6 in February; and the thermometers at 3 and 4 feet attain their maxima of 55°·9 and 55°·6, respectively, in August, and their minima of 42°·1 and 42°·6 in March.

It will be observed also that, at 4 feet below the ground, October is warmer than May; at 2, 3, and 4 feet below, September is warmer than June; and, at 4 feet, not only is December warmer than April, but November is warmer than May, all these being the exact reverse of what obtains above ground.

The temperatures below the ground tend to follow the same laws as temperatures on the surface of the sea in attaining their maximum later in the year than on the ground or above it, and their minimum later in the year than above the ground.

Another point of comparison is the variation of temperature between the warmest month and the coldest, which, referring again to Table I., is, at 1 foot, 16°·7, at 2 feet, 15°·0, at 3 feet, 13°·8, at 4 feet, 13°·0, that at 4 feet above the ground being 16°·6. It will also be observed that these variations of the underground thermometers, like those previously referred to, are not similar, that between 1 and 2 feet being 1°·7, that between 2 and 3 feet, 1°·2, and that between 3 and 4 feet, 0°·8.

TABLE I.—MEAN MONTHLY GROUND TEMPERATURES, AT 9 A.M., 1880-1889.

Month.	Below Ground.				On Ground.	Above Ground.	
	1 ft.	2 ft.	3 ft.	4 ft.	Grass Min.	9 a.m. and 9 p.m.	9 a.m.
	°	°	°	°	°	°	°
January....	40·5	41·7	42·5	43·2	32·3	40·3	40·3
February ..	40·7	41·6	42·1	42·7	34·0	40·7	41·2
March	40·5	41·8	42·1	42 6	31·8	40·8	41·6
April	43·9	44 2	44·1	44·3	34·5	44·6	46·0
May	49·0	48·4	47·9	47·6	38·6	49·5	51·4
June	54·4	53·5	52·4	51·7	43·9	55·0	57·1
July	57·2	56·4	55·4	55 0	47·7	56 9	58 8
August	57·0	56·6	55·9	55·6	46 6	56·9	58·9
September..	54·4	54·8	54·7	54·7	43·8	54·5	56·3
October ..	49·0	50·3	51·2	51·5	38·5	48·6	49·8
November ..	45·2	46·7	47·6	48·2	35·9	45·2	45·6
December	41·8	43·6	44·5	45·3	31·7	41·4	41·4
Year	47·8	48·3	48·4	48·5	38·3	47·9	49·0

It is curious, too, that the greater variation at 1 foot below the ground should be slightly more than at 4 feet above it, but this is partly caused, no

[1] These comparisons are made with the temperature at 9 a m. and 9 p.m., not with that at 9 a.m. only.

doubt, by the former temperatures being taken at 9 a.m. only when the temperature varies more than at 9 p.m. The thermometer at 1 foot below the ground registers, as might have been expected, the lowest temperatures of the four in the coldest months, viz. January, February, March, April, October, November, and December, and the highest temperatures in the warmest, viz. May, June, July, and August.

As regards the thermometers at 2 and 3 feet, that at 2 feet is warmer than 3 feet in April, May, June, July, August, and September, and colder in the other months.

It will be seen that in all cases there is practically no rise of temperature from the lowest point till April, and that it then increases less rapidly at 2 feet than at 1 foot, at 3 feet than at 2 feet, and at 4 feet than at 3 feet, till between June and July, when the process is reversed and the lowest thermometer increases most rapidly. Between August and September a general decrease begins, being most rapid at 1 foot, and least rapid at 4 feet, and so continues till between December and January, when the lowest thermometer again descends most rapidly.

It will be observed from Table II. that the temperature under the ground varies less from year to year than that above it. Thus, in the years before us the year 1881, taking an average of the temperatures at from 1 to 4 feet, was the coldest both below and above ground, and the year 1884 the warmest. The mean difference between the temperature below ground of 1884 and 1881 was 1°·7, and that above ground 2°·2.

TABLE II.—YEARLY GROUND TEMPERATURES AT 9 A.M., 1880-1889.

Years.	Below Ground.				Grass Min.	Above Ground 4 ft.
	1 ft.	2 ft.	3 ft.	4 ft.		
	°	°	°	°	°	°
1880	48·6	48·9	48·9	48·9	40·2	48·4
1881	47·0	47·6	47·5	47·8	37·9	46·8
1882	48·2	48·3	48·1	48·6	40·0	48·6
1883	47·5	48·0	48·0	48·4	39·1	47·6
1884	48·1	49·1	49·3	49·3	39·3	49·0
1885	47·0	47·6	47·7	47·9	37·6	47·2
1886	47·2	47·5	47·6	47·9	38·4	47·2
1887	47·7	48·4	48·6	48·8	36·1	47·8
1888	47·2	47·5	47·5	48·0	37·0	47·5
1889	48·6	49·0	48·9	49·0	37·3	48·3

There appears to be comparatively very little connection between the temperature on the ground (grass) and below it, as the temperatures below the ground both, from year to year and from month to month, follow those at 4 feet above the ground much more closely than those on the ground.

DISCUSSION.

Dr. W. Marcet said that having recently had occasion to make an investigation concerning earth temperatures, the question had arisen in his mind as to whether a thermometer enclosed in an iron tube sunk in the soil was the best form of exposure for ascertaining the temperature of the earth. In order to

satisfy himself on this point he had a special thermometer constructed and buried in the soil, its bulb being two feet below the surface, and compared its indications with those from a thermometer placed in an iron tube (the usual form of earth thermometer) at a similar depth in the ground. The results of this comparison showed that the indications of the two instruments accorded very closely, the thermometer in contact with the soil reading about 0°·5 lower in cold weather, and the difference becoming less in warmer weather. The comparative observations were carried on from February to May of the present year, and were brought to an end through the breakage of the thermometer buried in the soil.

Mr. J. G. SYMONS said that the statement made by Dr. Marcet was very satisfactory, as he (Mr. Symons) had always advocated the exposure of earth thermometers in iron tubes. A comparison between Mr. Moore's observations and the results of a series of 21 years' similar observations at Munich, published by Dr. K. Singer, showed that both agreed very well together, and followed the known laws concerning the distribution of temperature below the earth's surface.

Fogs reported with Strong Winds during the 15 years 1876-90 in the British Isles.

By ROBERT H. SCOTT, M.A., F.R.S.

[Received May 31st.—Read June 20th, 1894.]

In the paper which I had the honour of submitting to the Society in June 1893, and which was printed in the *Quarterly Journal*, Vol. XIX. p. 229, attention was drawn to the instances of the occurrence of fog with forces of wind of 6, and upwards, on Beaufort's scale, and that portion of the paper received special notice in the discussion of the entire communication.

It has since struck me that the conditions under which these fogs were reported were worthy of further study, and that the Society might possibly tolerate a further notice on the subject. I venture therefore to submit the results of some investigations into this somewhat obscure phenomenon.

Firstly, the conditions of pressure under which these fogs have been reported have been examined, in order to learn whether these were cyclonic or anticyclonic.

Secondly, the actual weather reported on each occasion has been noted, whether simply "f," or qualified by any other letter or letters, such as "o, u, d, f," (overcast, ugly, drizzle, and fog,) which was the report for Dover on November 28th, 1878. It should be remembered that these letters are intended to convey an account of the weather which has prevailed during the preceding twenty-four hours, and that they do not imply that all the different phenomena described appeared at once.

Thirdly, there have been extracted not only the temperature for the hour at which the fog was reported to have been present, but also the maximum

temperature for the 24 hours to which the observation belonged. It is evident that if the fog occurred at 6 p.m. this maximum temperature, recorded next morning, represents the true maximum for the day on which the fog was reported; but that if the fog was reported at 8 a.m. the maximum temperature then observed would refer to the 24 hours preceding that particular epoch.

Fourthly, the rain has been extracted for the preceding and the succeeding days, except in the case of the 6 p.m. fogs, where the only entry is that for the day of which 6 p.m. is nearly the middle point, that is the rain reported at 8 a.m. next morning.

To each case a few notes are appended, as to the general conditions of pressure and weather prevailing at the time.

In the first place it should be remarked that these fogs do not occur with typical anticyclonic conditions. This fact is obvious, inasmuch as a wind force of 6, Beaufort scale, implies steep gradients, and these are incompatible with the existence of an anticyclone. The fogs can only occur on the outskirts of the anticyclone, and as usually cyclones press rather closely upon anticyclones, it is often somewhat difficult to decide to which system the reported fog properly belongs, whether to the cyclone or the anticyclone. An attempt has, however, been made to form a judgment on each case, and, as a result, the accompanying table is submitted, showing the number of the fogs attributed to each category, referred to winds from each quadrant of the compass.

As to the total number of strong wind fogs, the number given in the original paper was 128, but subsequent inquiry had added 7 to the list, and the total now given for the 15 years is 135.

The following is the classification :—

Win 's from	Cyclonic	Anticyclonic or doubtful	Total
N to ENE ...	7 ...	0 ...	7
E to SSE ...	13 ...	5 ...	18
S to WSW ...	81 ...	14 ...	95
W to NNW ...	7 ...	8 ...	15
Total	108	27	135

In 12 instances fog was reported at more than one station at the same hour.

As regards precipitation, it need scarcely be said that in general none occurs with ordinary fogs. In the case of the strong wind fogs, now under consideration, this is far from being a correct statement, although dryness is the predominant condition of those classed under anticyclones. Of the 27 cases of the latter class of fog 21 were dry, or at least unaccompanied by as much as 0·1 in. of rain. Of the 108 cases classed as cyclonic fogs only 30 were dry to the same extent, and 78 were either accompanied with, or followed

immediately by, rain, sometimes heavy, and in 18 cases exceeding half-an-inch. It is therefore evident that the majority of these fogs are essentially wet fogs.

We now come to the question of the temperature accompanying these fogs, and here a very remarkable relation comes out. The temperature at the epoch of these fogs is not uncommonly the maximum temperature of the day.

All the cases have been picked out in which the temperature at the time the fog was reported either agreed with the maximum for the day or fell only 1° below it.

Of the 27 anticyclonic fogs 11 fulfilled this condition, and of the 108 cyclonic fogs 61 fulfilled it.

Accordingly, out of the whole number of 135 fogs no less than 72, or 54 per cent., occurred with temperatures either agreeing with, or very close to, the maximum for the day. If we take in the temperatures differing 2° from the maximum we increase the total of warm fogs to 92 and the percentage to 69.

Such a condition as this is rare in the case of our ordinary calm weather fogs. These occur usually with a sky clear above the fog, as is evident to everyone, and when radiation is consequently active; for frequently when a fog is dense enough at the surface of the ground, the sun, or moon, as the case may be, is visible through the fog, whereas any ordinary cloud suffices to obscure these luminaries entirely. However, this question of the relation of fogs in general to temperature seems to promise further results of interest, and it may be possible to find material for further communications if the Society should wish to receive such.

It appears interesting to examine into the relation of these strong wind fogs to storms. They sometimes occur with actual gales, and there were 11 such instances among the fogs classified as cyclonic. No less than 25 cases are put down as "preceding severe gales." That fogs sometimes occur just before gales is well known, and several such instances will occur to most persons' memories. They are frequently only the last dregs of a regular anticyclone fog, to be dispersed by the incursion of the gale.

All the considerations put forth in this paper appear to show that we have had to deal with a class of phenomena quite distinct from those accompanying the typical fogs of a London winter.

The fact of a high temperature heralding a winter gale is well known, and as these strong wind fogs occur much more frequently with winds from the quadrant from South to West-south-west than with other winds, the Southerly winds being the winds in the front part of the cyclonic system, it may be expected that the fogs will also be accompanied by high temperature.

The overwhelming majority of these cyclonic fogs with South-westerly winds—81 out of 108—and their much greater prevalence on the south-west coast (Scilly, Pembroke, Prawle Point) than elsewhere, point distinctly to their marine origin. They come in to us from the Atlantic Ocean.

They are apparently very thick mist, or very dense rain, and, in my opinion, as expressed in my previous paper, they should not receive the name of "fog," but that of "mist,"

Cyclonic Fogs.

Winds from N to ENE.

Date.	Station.	Weather.	Wind.	Temperature.		Rain.		Notes.
				Max. Temp.		Preceding.	Succeeding.	
				°	°	In.	In.	
1877. May 19	Stornoway	d f	NNE	47	51	·12	·02	On Northern side of shallow depression
,, ,,	Sumburgh Head	f	ENE	46	*	·11	·01	
1878. Nov. 28	Dover	o u d f	NNE	46	48	·11	·64	In middle of secondary over Straits of Dover. NE gale in Channel
1879. April 10	Scilly	o f	NNE	46	53	·01	·03	Stiff NE breeze in Channel
,, May 30	Sumburgh Head	f	NE	49	59	·00	·00	Cyclonic, complex situation
1881. Jan. 19	Pembroke	b o f	NE	28	32	·00	·05	(Snow.) Day after "blizzard"
1886. April 20	Yarmouth	f g	ENE	42	46	·00	·01	Strong E winds

Winds from E to SSE.

				°	°	In.	In.	
1876. Nov. 15	Wick	f	SE	50	*	·81	·00	1·77 in. Aberdeen; 1·50 in. Ardrossan; exceedingly heavy rain about; depression off North-west Coasts
1877. Jan. (	Roche's Point ..	r f	SE	48	49	·22	·75	Before heavy South gale
1879. Feb. 10	Scilly	o d f	SSE	50	51	·24	·11	Barometer very low, see SSW, Pembroke
,, Mar. 25	Dover.....	o f s	E	33	36	·02	·04	Before E gale, force 10 at Scilly
,, July 31	Pembroke	o f	SSE	58	62	·19	·08	Small shallow depression off Cork. See Scilly, SSW
,, Sept. 7	Wick	f	SE	53	55	·03	·01	Before slight gale; fog very general on NE coasts
1880. Mar. 16	Scilly	r f	ESE	48	49	·01	·16	SE gale in Ireland; before
,, ,, 17	Scilly	r f	E	49	*	·16	·37	E gale Scilly
1881. Feb. 14	Pembroke	r f	SE	43	45	·36	·35	In slight gale. See Scilly, S
1882. April 22	Roche's Point ..	r f	SE	51	55	·24	·25	Depression advancing to Ireland from West
1883. Mar. 21 6 p.m.	Hurst Castle....	f	ESE	39	45	..	·06	Before East gale
,, June 26 6 p.m.	Wick	f	ESE	58	*	..	·00	Before gale, SSE 9; Stornoway
1887. Jan. 11	Pembroke	f	SSE	48	*	·40	·17	In gale in front of a "V" shaped depression

Winds from S to WSW.

				°	°	In.	In.	
1876. Jan. 29	Valencia	f	SSW	49	51	·03	·93	Depression outside North-west of Ireland
,, Jan. 30	Pembroke	f	S	48	*	·09	·09	
,, Feb. 17	Pembroke	f	SW	49	*	·40	·16	Heavy rain all about
,, Feb. 28 6 p.m.	Scilly	f	SW	52	55	..	·16	Rain very general
,, Mar. 3	Pembroke	o f	SW	49	*	·12	·02	Beginning of slight gale
,, Sept. 26	Scilly	o f d	WSW	58	65	·27	·01	Depression over Cork, moving eastwards

CYCLONIC FOGS.

Winds from S to WSW—*Continued.*

Date.	Station.	Weather.	Wind.	Temperature. Max. Temp.		Rain. Preceding.	Rain. Succeeding.	Notes.
				°	°	In.	In.	
1876. Dec. 29	Roche's Point ..	r f	S	50	52	·18	1·26	Stiff SW gale coming on
1877. Jan. 16	Scilly	f	SSW	52	*	·07	·15	Next day 0·4 of rain exceeded at 6 Western Stations
,, Jan. 23	Roche's Point ..	r f	S	50	*	·12	·45	Preceded heavy rain for 2 days in S. of Ireland. 0·7 and 0·8 at Valencia. Slight S gale
,, May 17	Scilly	o d f	WSW	54	57	·74	·00	In centre of small depression moving East
,, June 2	Pembroke	r f	SW	52	56	·46	·03	In stiff breeze, not heavy gale
,, ,,	Scilly	d o f	SW	55	57	·04	·01	
,, Aug. 27 6 p.m.	Scilly	f	SW	62	64	..	·05	Preceded stiffish breeze
,, Aug. 27	Pembroke	o f r	SW	61	62	·49	·20	
,, Oct. 30	Roche's Point ..	r f	SSW	55	57	·11	·15	Preceded SW gales
,, Dec. 28	Roche's Point ..	r f	S	47	*	·25	·40	Preceded stiff breeze and very heavy general rain
1878. Jan. 20	Scilly	f	SW	51	52	·05	·02	
,, Feb. 15	Scilly	f d	SSW	52	*	·09	·05	
,, ,, 6 p.m.	Hurst Castle....	f d	SW	49	50	..	·07	Strong SW winds, occasionally force 8
,, Feb. 16	Scilly	o f	S	50	53	·05	·04	
,, Feb. 28	Scilly	f d	SW	53	*	·16	·11	Before slight gale
,, Apr. 13	Scilly	f d	S	52	54	·86	·02	Depression lying off W of Ireland, 1·15 rain Valencia. 0·96 Roche's Point
,, Nov. 24 6 p.m.	Scilly	f	SSW	52	54	..	·13	In front of small depression
,, Dec. 30	Dover	o f r	WSW	49	*	·08	·23	Before SW gale
1879. Jan. 13	Scilly	f d	WSW	51	*	·12	·25	Probably cyclonic. Anticyclonic over France
,, Feb. 9	Pembroke	f	SSW	47	48	·58	·03	Very complex system, bar. 29·19. See Scilly, SSE
,, April 7	Wick	f	S	42	49	·01	·35	Very heavy rain Aberdeen and Thurso; before slight SE gale
,, June 19	Scilly	o f	S	53	57	·03	·22	Before and in South gale
,, July 7	Scilly	f d	WSW	57	60	·13	·02	Before WSW gale
,, July 19 6 p.m.	Scilly	f	SW	58	*	..	·32	In gale
,, July 20	Pembroke	f	WSW	56	57	·34	·06	In a gale
,, ,,	Prawle Point ..	f	SW	56	58	·48	·00	
,, July 31	Scilly	o f p	SSW	60	62	·21	·08	See Pembroke, SSE
,, Aug. 20	Scilly	f d	SSW	62	*	·42	·16	Very heavy rain about. 1·21 Hurst, 1·13 Oxford
,, Sept. 2	Ardrossan	f d	SSW	53	58	·28	·29	Fresh winds, slight gale Mullaghmore
,, Dec. 28	Pembroke	o f	SW	49	50	·19	·08	Before and in gale
1880. Feb. 20 6 p.m.	Scilly	f	SW	49	52	..	·04	Heavy gale in North, forces 9 and 10
,, Dec. 22	Pembroke	r f	WSW	52	*	·44	·20	Before gale
1881. Feb. 13 6 p.m.	Scilly	f d	S	50	52	..	·35	In slight gale, force 7 at seven stations. See Pembroke, ESE
,, Dec. 24	Ardrossan	o f	S	44	*	·00	·62	In gale, anticyclone just broken up

CYCLONIC FOGS.

Winds from S to WSW—*Continued.*

Date.	Station.	Weather.	Wind.	Temperature.		Rain.		Notes.
				Max.	Min.	Preceding.	Succeeding.	
				°	°	In.	In.	
1882. Jan. 5	Valencia	f g	WSW	53	°	·49	·10	Before gale
,, Jan. 6	Ardrossan	b f	WSW	44	50	·43	·21	In heavy gale
,, June 5 6 p.m.	Scilly	d f	SW	57	58	..	·58	
,, July 14 6 p.m.	Scilly	r f	S	59	63	..	·35	In slight gale
1883. May 12	Holyhead	f q	SSW	50	51	·17	·07	Slight gale; force 7 at several stations, 9 at Valencia
,, ,,	Prawle Point ..	f	SSW	50	51	·46	·00	
,, May 13	Holyhead	r f q	SSW	50	54	·07	·00	
,, Aug. 9	Liverpool	f	WSW	55	66	·47	·00	Before gale
,, Oct. 13 6 p.m.	Scilly	f d	S	57	58	..	·22	Heavy gale in two days
1884. Jan. 23	Pembroke	f	SSW	50	51	·22	·26	In gale
,, ,,	Prawle Point ..	f	SW	50	°	·23	·08	
,, ,,	Hurst Castle ..	o d f	SW	49	50	·06	·18	
,, May 15 6 p.m.	Pembroke	f	SW	51	52	..	·01	Fog very prevalent about
1885. Feb. 26 6 p.m.	Pembroke	f	SSW	47	48	..	·37	In slight gale
,, Sept. 14 6 p.m.	Pembroke	r f	SSW	59	60	..	·11	Strong SW winds, much fog in Channel
,, Nov. 29	Pembroke	r f	SSW	53	°	·33	·25	Gale in Ireland
1886. Mar. 1 6 p.m.	Hurst Castle ..	d f s	SW	45	°	..	·50	In gale
,, Mar. 26 6 p.m.	Scilly	f d	SSW	51	52	..	·05	In gale
,, ,,	Pembroke	f	SSW	46	47	..	·60	
,, Mar. 27	Pembroke	f	SSW	46	47	·60	·22	
1888. Mar. 8	Holyhead	o f q	SSW	45	48	·05	·20	Before gale
,, ,,	Prawle Point ..	f	SSW	46	48	·12	·20	
,, Mar. 9	Prawle Point ..	f w	SSW	47	48	·20	·04	
,, Mar. 10	Hurst Castle....	f	SW	43	46	·25	·51	In slight gale
,, June 15 6 p.m.	Hurst Castle....	f	WSW	55	56	..	·04	Small depression over South of England
,, Nov. 15	Pembroke	r f g	SSW	54	°	·53	·05	Before and in heavy gale on 16th
,, ,,	Prawle Point ..	r f	SSW	55	56	·08	·07	
,, Nov. 16	Pembroke	o f q	SSW	55	°	·05	·02	
,, ,,	Prawle Point ..	f	SSW	55	56	·07	·02	
,, Dec. 5 6 p.m.	Scilly	f	WSW	55	°	..	·17	In stiff breeze
1889. Feb. 1	Scilly	f	WSW	52	°	·04	·12	Before gale, fog extremely prevalent. See also W. ? Anticyclonic
,, ,,	Holyhead	q f	SSW	49	53	·02	·02	
,, ,,	Hurst Castle....	f	WSW	47	48	·01	·09	
,, ,, 6 p.m.	Dungeness	f	WSW	48	°	..	·00	
,, Aug. 3	Holyhead	f g	SW	59	64	·60	·00	In slight gale
,, ,,	Prawle Point ..	f u	SSW	60	63	·23	·15	
,, Dec. 21 6 p.m.	Scilly	r f	SW	51	53	..	·45	Strong SW winds in Channel
1890. Jan. 9 6 p.m.	Scilly	f p	SW	53	°	..	·12	Strong SW winds in Channel
,, ,,	Prawle Point ..	f	SW	52	°	..	·15	
,, Jan. 13	Pembroke	r f	SSW	50	°	·05	·03	Slight gale
,, June 30	Hurst Castle ..	r f	SSW	56	63	·31	·18	In gale

Cyclonic Fogs.
Winds from W to NNW.

Date.	Station.	Weather.	Wind.	Temperature. Max. Temp.		Rain. Preceding.	Rain. Succeeding.	Notes.
				°	°	In.	In.	
1877. Nov. 21	Pembroke	r f	W	53	*	·28	·21	Preceded heavy gale
1878. Jan. 22	Pembroke	o f	W	51	52	·12	·03	Preceded Westerly gale
1879. Jan. 7 6 p.m.	Scilly	f	WNW	50	52	..	·50	Before and with heavy general SE gale
,, March 5 6 p.m.	Pembroke	f	WNW	45	48	..	·04	Slight SW gale on preceding day
1883. Oct. 7	Sumburgh Head	f	W	53	*	·39	·01	Before W gale in Norway
1889. Jan. 31 6 p.m.	Scilly	f	W	52	*	..	·04	See also WSW
1890 April 7	Dungeness	f	W	46	49	·01	·07	Fresh W winds

Anticyclonic or Doubtful Fogs.
Winds from E to SSE.

				°	°	In.	In.	
1876. April 7 6 p.m.	Scilly	f	ESE	49	54	..	..	Anticyclone moving off, depression just showing itself
1886. May 22 6 p.m.	Roche's Point	f	SSE	47	50	..	·35	Outskirts of anticyclone
1887. Jan. 26 6 p.m.	Scilly	o f	SSE	50	*	..	·01	Edge of retreating anticyclone
,, March 3 6 p.m.	Scilly	o f	E	47	48	..	..	Anticyclone, but local depression off South Coast of Ireland
,, March 4	Scilly	o f	E	44	48	.	..	

Winds from S to WSW.

				°	°	In.	In.	
1880. Jan. 5 6 p.m.	Scilly	f d	SSW	51	52	..	·10	Anticyclone
,, March 4 6 p.m.	Pembroke	f	WSW	48	*	..	·02	Doubtful
,, March 5	Pembroke	o f	WSW	48	*	·02	·01	Doubtful
1881. Mar. 10	Scilly	o f	WSW	50	52	·01	·02	Fog very general. Anticyclone
,, May 6	Pembroke	f	SW	50	*	·01	..	Anticyclonic, but gales in the the North. W S Stornoway for 2 days, increasing to W 9, and extending to Wick on 7th
,, Aug. 3	Holyhead	f q	SSW	59	64	·06	..	Doubtful
1882. Mar. 10	Scilly	f	SW	52	55	·02	·03	Anticyclone
,, Aug. 6	Stornoway.....	f	WSW	58	63	..	..	Outskirts of anticyclone
,, Aug. 20 6 p.m.	Scilly	f d	SW	61	63	..	·02	Anticyclonic
1884. Aug. 9	Wick	f	S	56	65	..	..	Possibly anticyclonic
1885. June 18 6 p.m.	Pembroke	f	SSW	54	58	..	·04	Edge of anticyclone
1886. June 14 6 p.m.	Hurst Castle....	f	WSW	55	62	..	·01	Much fog about
1889. Mar. 24	Hurst Castle....	o f d	WSW	45	49	·02	·03	Anticyclonic
1890. June 5	Hurst Castle....	f d	WSW	55	58	·97	·04	Doubtful

ANTICYCLONIC OR DOUBTFUL FOGS.
Winds from W to NNW.

Date.	Station.	Weather.	Wind.	Temperature. Max. Temp.	Rain. Preceding.	Rain. Succeeding.	Notes.
				° °	In.	In.	
1877. Feb. 8 6 p.m.	Scilly	f	W	52 53	..	·09	North side of anticyclone
,, July 19	Scilly	f d	W	60 61	·19	·04	North side of anticyclone
1879. Oct. 22	Scilly	o f	W	56 *	·02	·01	Anticyclone
1881. Mar. 10	Jersey	o f r	W	48 51	·01	·01	See also WSW Scilly
,, Aug. 12 6 p.m.	Scilly	r f	W	61 *	..	·25	Anticyclone close by
1887. Jan. 19 6 p.m.	Pembroke	f	W	48 49	..	·27	Edge of anticyclone
1888. Jan. 8	Dungeness.....	f	W	45 50	..	·01	Anticyclone
,, Jan. 22	Scilly	o f	WNW	49 51	·16	·01	Anticyclone coming on

In the preparation of the paper I have received great assistance from Mr. Gaster.

In the column for "maximum temperature" an asterisk indicates that it was the same as that at 8 a.m.

DISCUSSION.

Capt. D. WILSON-BARKER said that he entirely agreed with Mr. Scott's definitions of fog and mist, and had always regarded mist as being more or less moist. Although the fog observations dealt with in the paper had been classified under two heads, viz. cyclonic and anticyclonic, he had no doubt that there was a well marked area between cyclonic and anticyclonic conditions where fogs might be met with.

Staff Capt. TIZARD said that a better definition of what was comprised in the term "fog" was greatly needed. He noticed that in the tables, snow was entered as accompanying fog at two of the stations. He had never himself observed fog and snow simultaneously, and was inclined to think that the conditions of weather described under the term "fog" in each of these cases was simply a state of the atmosphere which a seaman would describe as "dirty thick weather." The observations used in the tables were all from land stations, and it appeared desirable that these should be compared with such observations on the adjacent seas as might be available. His own idea of fog was that condition of the atmosphere unaccompanied by any precipitation, in which objects at a distance of half a mile were obscured; and he should describe the fog as thick when objects 100 yards distant were not visible. Some scale of fog measurement, by means of the degree of visibility of surrounding objects, seemed necessary.

Mr. C. HARDING said that the weather authorities in the United States issued forecasts of fogs over the banks of Newfoundland, basing their predictions upon the movements of areas of low pressure, it being, of course, evident that when the warm air in the front of a depression met the cooler air over the cold Arctic current flowing over these banks, thick fog must naturally result. Did the term "in a gale," which frequently occurred in the tables accompanying the paper, mean that the fog occurred in a gale, or merely that it was observed in a cyclonic disturbance? He had consulted the charts of the weather over the North Atlantic for each day during the thirteen months, August 1882 to August

1883, as published by the Meteorological Council, in order to see whether fog usually prevailed when gales were blowing, and had found that it was quite a common occurrence for mist to be observed with gales, especially on the southern side of depressions. As all the stations used in Mr. Scott's investigation were situated on the coast, it appeared desirable to consider the temperature of the sea as well as that of the air.

Mr. F. GASTER said that he hoped this paper would assist in getting rid of the confusion which existed in the use of the terms "fog" and "mist," these terms being intended to describe two distinct classes of phenomena, the one existing with a low temperature, a high barometer, and a calm and dry atmosphere, while the other prevailed when the barometer was low and the temperature high, the wind being strong and the air damp. These two conditions only possessed one common characteristic (that of obscuration), and it was a great mistake to register both phenomena under the same name. As regards the effect of these two varying atmospheric conditions upon the human body, a physician had recently told him that while the one caused excessive irritation of the mucous membrane, the other had no such effect, but was chiefly detrimental to health through producing severe colds. It had probably been often noticed that in an anticyclone, when dry and cold fogs occur, a change would take place without any apparent cause; but he had found, on carefully looking into such instances, that the alteration in atmospheric conditions was brought about by the formation of a very shallow disturbance at the time in the neighbourhood of the district affected.

Mr. R. H. CURTIS thought some confusion was likely to be caused by the way in which the term "dry fog" was used. Disregarding the smoke fogs of London and other large manufacturing towns to which they were peculiar, and which were generally dry and always irritating enough, the fogs which were experienced in rural districts and at sea were invariably composed of water particles, and that being so, it could hardly be correct to call them "dry" under any conditions. It was true that at times these water particles were more minute than at others; and if the fogs were considered simply with respect to their power of wetting surfaces exposed to them, some were relatively dry as compared with others, the fog becoming wetter as its constituent water particles became larger and more numerous, which again was a condition largely due to the temperature of the bodies of air whose commingling was usually the cause of the fog. Mr. Scott had remarked in his paper that the fogs generally occurred with the maximum temperature of the day, but was it not the case that when fog prevailed the temperature was steady and no daily range was apparent?

Mr. G. J. SYMONS said that until Mr. Curtis had spoken he thought he saw a solution of the difficulty of deciding between fog and mist, fog being a dry obscuration of atmosphere, and mist a wet obscuration, consequently "sea fog" would have become "sea mist"; but, as the last speaker rightly said, a dry fog was really a most uncommon occurrence, and was, in fact, an artificial production, so that the settlement of the difference between the phenomena described by the terms "mist" and "fog" appeared to be no nearer than before. Mr. Scott's paper was undoubtedly a valuable piece of work, but hardly concerned London, as all the data referred to seaside stations. Regarding the visibility of objects in fog, he should be glad to know whether the visibility of an object through fog was entirely dependent upon the angle subtended (allowance, of course, being made according to distance and illumination), or whether absolute magnitude had anything to do with it. The degree of visibility during a fog depended on the amount of illumination.

Mr. H. N. DICKSON said that there appeared to be a simple physical explanation of the difference between mist and fog. In fog, vapour was condensed on dust nuclei from an unsaturated atmosphere in sufficient amount to make the particles visible. London fog required little vapour for its formation, for the dust particles were originally large and easily cooled by radiation, and a slight increase of size was sufficient. At sea the dust particles were saline and attracted moisture. When the air was saturated or nearly so the fog particles had each an increased allowance of water, and parted with it to surrounding objects, the characteristic of mist.

Mr. R. H. SCOTT in reply said that the observations of fog were taken as re-

ported by the observers in the *Daily Weather Report* at 8 a.m. and 6 p.m. It was a difficult matter to consider fogs in relation to the centres of cyclones and anticyclones, as it could not frequently be determined where the cyclone began and where the anticyclone ended. No ships' logs had been taken into consideration, and, in fact, there were very few observations from ships' logs close to the coasts, as many ships did not commence to keep logs until quite clear of the British Islands. A scale of visibility of objects at known distances, for the purpose of measuring the amount of fog obscuration, had been arranged at the Kew Observatory and carried on for two years, but some difficulty, chiefly due to unequal illumination, had been experienced in making observations. The objects observable were also all situated in directions from north-west round by east to south-east; the rest of the horizon being limited by Richmond Hill or by trees. As regards the issue of forecasts of fog for the banks of Newfoundland, it must be remembered that there was no similar condition of ocean currents prevailing in the seas round the British Isles as was the case at Newfoundland. The note "in a gale," to which Mr. C. Harding had drawn attention, was intended to mean that a wind force of 7 or 8 was observed somewhere in the British Islands at the time of the occurrence of the fog. As regarded the use of sea temperatures in connection with this investigation, very few satisfactory and trustworthy observations of sea temperature were available, and he (Mr. Scott) did not anticipate that sudden changes of sea temperature would be found to occur.

SOME CHARACTERISTIC FEATURES OF GALES AND STRONG WINDS.

By RICHARD H. CURTIS, F.R.Met.Soc.

(Plate V.)

[Received June 5th.—Read June 20th, 1894.]

There is probably no branch of meteorology about which so little is really known as wind measurement, and yet there is no other which is of more general importance or which is more far-reaching in its bearings upon other branches of the science. But directly we get beyond the general statement that wind is a result of solar action, and ask more particularly as to the causes by which its infinitely varied movements are determined and governed, we find ourselves in a domain in which theory abounds, but in which ascertained facts are conspicuously rare. We know, for example, that some relation exists between barometrical gradients and wind force, but of the causes which produce those gradients, and modify them, by varying the intensity of areas of high or low pressure, we know scarcely anything at all. And not only is this true as regards the broader features of the subject, but it is so also with respect to details as to which it might have been supposed that meteorologists would long ago have found out all that was to be known. For years we have had all over the country an army of observers, most of whom are

enthusiastic and intelligent, and yet after all they have done we still know next to nothing as to the manner in which the wind blows, of its strength or velocity, of the nature of its pulsations, its squalls and its lulls, or of the way in which its dynamic force is exerted upon obstacles opposed to its path.

Or if we look at our instrumental appliances for obtaining information on these points, we find a state of things which may fairly enough be termed chaotic. We still use without comment appliances yielding results which are at least doubtful to a very high degree; we put our anemometers up on sites which we know are fatal to their integrity; and quietly ignoring ascertained facts respecting them, we still use the results obtained from instruments of different patterns, and known to be in their present state non-comparable, as if they all meant one and the same thing.

I have long felt it to be a fair matter of reproach to meteorologists, that while this is the state of the case so little effort should be made to remedy it. Of course I know perfectly well the inherent difficulties in the way of advance in certain directions—perhaps no one knows them better,—but still there are some branches of the subject in which I venture to think that very much might be done by intelligent observers, even without elaborate mechanical appliances, if only systematic and thoughtful attention were given to them.

I have mentioned these matters, since they afford the reason why I have brought the present paper before the Society, for they appear to me to justify one in making any contribution, however small, to our knowledge of a subject about which so little is known.

In a paper[1] which I read before the Society in 1881, I drew attention to the evidence of very high velocities of wind which was afforded by the traces obtained from the Robinson Cup Anemometers at some exposed stations. I pointed out that although the records of that class of instrument were not well suited for giving velocities for short periods, owing to the great reduction

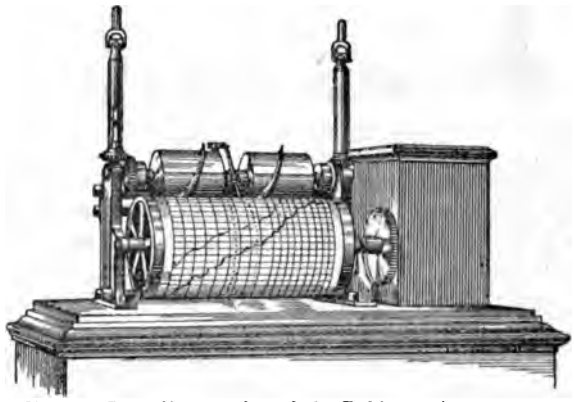


FIG. 1.—Recording portion of the Robinson Anemometer.

which the revolutions of the cups underwent before registration, yet the traces often showed decided angular changes which clearly indicated that large increases of velocity took place, but which, lasting only for a short time, were

[1] *Quarterly Journal*, Vol. VII. p. 205.

not recognisable in the general result obtained when the run of the cups over sixty consecutive minutes was measured, as is usually done in tabulating the records. In the large size Anemometer, with 9 inch cups and arms of 2 feet radius, the recording portion of which is shown in fig. 1, 7,000 revo-

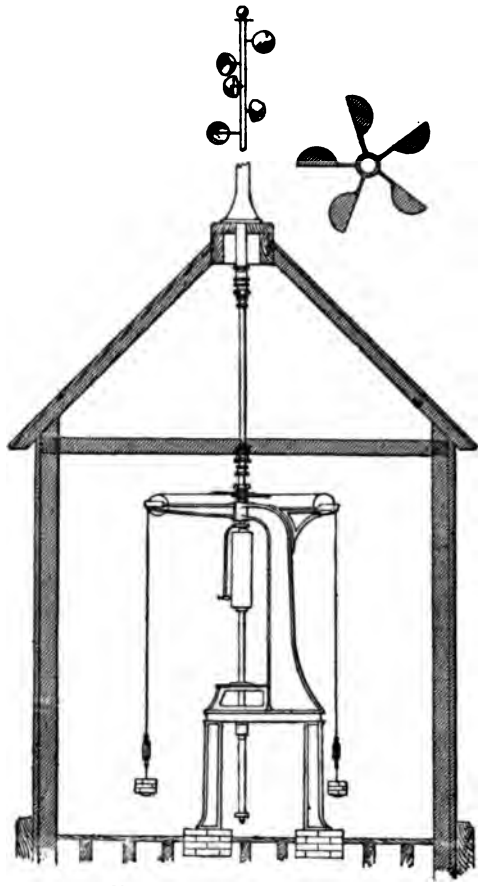


FIG. 2.—Bridled Anemometer.

lutions of the cups are required to produce a piece of trace 2¾ inches long, representing the passage over the instrument of 50 miles of wind. The case is similar to that of a train which makes a run of so many miles in an hour, but which does so by running at varying speeds, slowly up steep inclines and rapidly down others, the slower and the faster rates being merged in the actual nett result for the hour.

Since then I have had opportunities of more thoroughly studying this subject from other points of view, and I wish now to call attention to some conclusions I have obtained, mainly from a study of the records yielded by the Bridled Anemometer, devised by Sir George G. Stokes, F.R.S., and erected by the Meteorological Council at Holyhead.

The construction of this instrument will be understood by a reference to fig. 2. It consists of five hemispherical cups attached by short arms to a

vertical spindle, upon which they are arranged spirally and in such a way that no cup shall interfere with the one immediately behind it. The cups and spindle are not free to revolve with the wind, as in the case of the Robinson instrument, for their movement is checked by weights which have to be lifted as the spindle revolves, and the amount of torsion of the spindle is therefore the measure of the wind's force. The instrument, it will be seen, belongs to the class of pressure anemometers; but since the pressure varies as the square of the velocity, it has been designed so as to give an equal scale of velocity throughout. A large cylinder carries a sheet of paper which receives a record of every movement of the cups, and there is an arrangement by which the time-scale, which is normally seven-tenths of an inch to the hour, can be doubled, or if desired enlarged to about 48 times its normal size, or even more.

With the most open scale it is possible to follow every movement of the wind, and to obtain a good deal of insight into the manner of its working, but with the normal scale the gusts in gales of wind follow each other in such quick succession that the pencil produces a broad band of shading extending over some miles on either side of the average velocity, and it is only the gusts and lulls which extend beyond this belt which can be singled out from the others.

This instrument throws a considerable amount of light upon the question of maximum velocities to which I just now referred. For the reasons I have mentioned it is of course almost impossible to correlate individual gusts with the indications of increased velocities shown on the Robinson curves, but it is possible to do so with *groups of gusts*, and the comparisons of the two which I have made show that the estimates quoted in my paper were not far from the truth, when a proper allowance has been made for the fact that they were based on the assumption that Dr. Robinson's original factor (3), for the relation between the motion of the cups and that of the wind, was correct. I may mention that the scale of the Bridled Anemometer is based upon data recently obtained by Mr. Dines, and it will be remembered that other of his experiments led him to conclude that the factor (3) was about 30 per cent. too large.

The highest force of an individual gust that I have met with on the Bridled Anemometer was registered in December 1891, and amounted to a rate of 115 miles per hour, which with the old factor would be equivalent to a rate of about 150 miles per hour. Gusts at a rate of from 90 to 100 miles per hour have many times been recorded, but the usual limit for gusts in a strong gale may be taken to equal about 80 miles per hour, which on the old scale would be equivalent to about 120 miles per hour. It is necessary to bear in mind these old scale equivalents, because it is with them that the maxima formerly quoted must be compared.

The record obtained from the Robinson instrument will depend very much upon the character of the wind, and for this reason it is not always a very safe guide in forming a judgment as to the intensity of a gale. If a high hourly mileage is registered there can be no doubt that a very strong wind

must have prevailed to produce it, and yet it is possible that an even more destructive and dangerous wind should have prevailed with a smaller mileage indicated by the instrument; indeed, I have come to the conclusion that whilst the positive evidence of the Robinson instrument is valuable, its negative evidence must be accepted with the greatest caution, and is indeed worth little. These records are sometimes produced in Courts of Law as evidence when litigants wish to show that a gale did or did not prevail; in the latter case it would be only necessary to ask whether a heavy transient squall could not have occurred without its being indicated upon the trace in order to destroy entirely its value as evidence upon the point.

As a matter of fact, gales differ in character very much, as indeed do also winds which do not attain the strength of a gale. As the result of a prolonged study of their general features, as recorded by the bridled anemometer, I have for my own use divided them into three general classes, within which there are, of course, some fairly wide limits for variety.

In the first class I place those gales which are essentially *squally* in character—in which the gusts constitute the main feature of the gale. In such a case the gusts and lulls alternate very rapidly, and indeed the wind is never constant in force for many seconds together. Usually it oscillates over a range of perhaps 10 or 20 miles at a mean strength of probably 40 miles per hour, but every now and again it bursts out with a velocity of possibly 40 or 50 miles an hour above the average, and after a few seconds sinks to a rate of 10 or 20 miles below it. This is certainly the most usual character of the gales experienced on our coasts, although such gales vary immensely as regards the strength and frequency of the gusts and lulls, and also as to the average velocity of what may be called the "normal of the gale."

The trace which the bridled anemometer would make in such a gale may be thus described. At that part of the scale indicating a velocity of (say) 30 to 40 miles per hour there will be a band of flat shading, caused by the innumerable passages backwards and forwards of the pencil as it ranged over those limits with the oscillations of the wind, this is what I have termed the "normal of the gale;" above this band will be a less dark fringe, passing off into more or less isolated lines, made by the stronger gusts which have carried the pencil beyond the usual limits; while every here and there, at intervals of perhaps a few minutes, lines will start up, generally two or three quite close together, far above any others, marking the extreme limits of the gale. At the bottom of the belt of shading a similar appearance will be found caused by the lulls succeeding the gusts, but generally extending over a much more limited range of velocity. Fig. 1 (Plate V.) is a reduced reproduction of a portion of the record of such a gale, in which, however, the "normal" is much higher, whilst the range of the gusts above it is less, than is commonly the case.

The frequency with which the gusts follow each other varies, as I have said, immensely. I have, however, made an attempt to count them in cases where the use of the most open time-scale would allow of my doing so, and I think I may say that in an average gale the ordinary gusts follow each other at in-

tervals of about 10 to 20 seconds, while the extreme gusts occur at the rate of about one per minute. I only put this forward, however, as an approximation for the case of an average gale.

The range of velocity covered by the squalls is another point upon which gales differ very largely. In those to which I am now referring—squally gales—a range in rate of from 40 to 50 miles per hour above the "normal" is common, and may, I think, be regarded as a fair range for the extreme gusts in a fairly strong gale, while in a similar gale a total range of rate, from the lull to the following squall, of from 60 to 70 miles, or even more, is not unusual.

My second class of gales are those in which the velocity of the wind is tolerably steady, much steadier than in the first. The "normal" of the gale covers a much smaller range, perhaps not more than a rate of five or six miles per hour, and the gusts are far less severe; and I have noticed that generally they are not accompanied by lulls falling much below the "normal," or if the lulls are frequent then the gusts above the "normal" are comparatively few. This is a rather curious feature, but I have noticed it in several cases. Figs. 2 and 5 (Plate V.) are reduced facsimiles of portions of traces produced by gales of this class, the time-scale used in fig. 5 being a very open one.

The trace in this instance would be very different from that I have just described. The band of shading is much narrower, and as a rule far less flat, whilst the isolated lines above or below are much shorter and perhaps less numerous. It does, however, sometimes happen that the "normal" is even higher than in some of the more violent squally gales.

My third class should perhaps have been the second, inasmuch as it is a distinctly squally variety of gale. But the characteristic by which I distinguish it is peculiar. The record made by the anemometer has *two* "normals," connected by a lighter band of shading, as shown in fig. 3 (Plate V.). Indeed the gale appears to be made up of two series of rapidly succeeding squalls, the one series at a comparatively low rate of velocity, the other at a much higher one, the wind-force shifting rapidly and very frequently from the one series to the other. Examples of this class of gale are not very common, but those I have seen have been very well marked.

The trace in this case would show a very broad band of shading, with the upper and lower limits much darker than the centre, and having a good many isolated lines indicating gusts of considerable intensity projecting above the upper limit.

Before leaving the subject of gusts there are two other points to which I would like to call attention, and the first is as to their *duration*. As I have already said, the bridled anemometer is provided with an arrangement by which a time-scale of about ½ an inch to the minute can be used, and when this is in use in a gale of wind the duration of the gusts can be very fairly judged. In many instances they are very sudden in their occurrence; the rate rises to the maximum with great rapidity, remains there but an instant, and falls back again as quickly; the whole thing lasting but a second

or so. In many cases, however, it is different. I find with the bridled anemometer the same thing as I have since witnessed, times without number, with Mr. Dines's pressure tube anemometer, and which is the second point I wish to mention. The gust does not rise to its maximum at one bound. The pen or pencil rises some distance, then pauses, and perhaps recedes slightly, it then starts upwards again, and perhaps makes another pause before it finally reaches its maximum. When there it seldom rests long, but falls again as it rose, in stages, and I have measured many cases in which the gust remained at about its maximum, falling and rising 2 or 3 miles only, for several seconds; indeed, in one case, of which I have a note, it did so for more than half a minute, during the whole of which interval the velocity did not vary more than 6 miles. The action of the instrument under the influence of gusts and lulls is well shown in figs. 4 and 5 (Plate V.), in both of which an open time-scale was used.

The only other point to which I wish now to refer is one to which I do not think attention has been called before. On looking carefully over these records I have found, oftentimes very distinctly marked, a long pulsation in the wind force which recurs again and again with more or less regularity at intervals of perhaps 20 minutes or half-an-hour in some cases, and in others at longer intervals of about an hour, more or less. What I have before termed the "normal of the wind force" rises gradually, and as gradually subsides again; the quicker and larger oscillations of gusts and lulls going on all the while and quite independently of this long period oscillation. In some cases this phenomenon is more marked than in others, but it is very common, and I am inclined to think that in many instances where it is not very apparent its absence is due really to the more casual oscillations having in some way obliterated it.

Generally it is best seen on the traces by foreshortening them somewhat, and so getting a more generalised view of them, but in plenty of instances it stands out, as in fig. 6 (Plate V.), evident enough without doing this. The most violent gales are not those in which it is best seen; a moderate gale, or a strong wind which falls just short of the strength of a gale, are perhaps the cases in which it shows itself most evidently. When the gusts and lulls very rapidly succeed each other, and at the same time cover a wide range, it is less apparent without foreshortening. This feature of the wind-force is also shown very distinctly on the curves yielded by Mr. Dines's new pressure tube anemometer; and the regularity with which it recurs throughout the whole continuance of a gale, as well as the fact that it is of such common occurrence, leads me to think that it very probably plays an important part in the general movement of large masses of air, such as are involved in gales of wind, and that it is a phenomenon well worthy of further investigation.

The phenomenon is not to be confused with the passing gust which comes and goes in a few seconds, and in which the velocity probably rises considerably before it dies away again. In the case of the long pulsation the increase in the "normal" is always gradual, and may be very slight,

although very evident, and the pulsation is certainly not shown in the hourly measurements of velocity, owing to the fact that its period is fairly uniform, and therefore its effect becomes distributed pretty equally.

In conclusion, I beg to express my thanks to the Council of the Meteorological Office for their permission to make use of the curves of the Bridled Anemometer for the purposes of the paper.

DISCUSSION.

Mr. W. H. DINES said that he quite agreed with everything Mr. Curtis had said with reference to the chaotic state of anemometry, and as an instance he might mention the way in which the hand rail of the ladder by which the observer got up to the cups was sometimes left projecting, so that the eddy from it would just catch one side of the instrument as it turned. He was glad Mr. Curtis had based his results upon the Bridled Anemometer at Holyhead, as he thought that was the only trustworthy pressure instrument from which we had any records in England. He might state that he had constructed a scale for this anemometer at the request of the Meteorological Council. The identical cups now in use at Holyhead had been sent to him, and he had tried them at speeds up to 70 miles an hour upon the whirling machine at Hersham. The velocities quoted by Mr. Curtis were therefore quite independent of any question about the value of the factor of the Robinson cups. He had obtained the pressure upon a square foot circular plate on the same whirling machine, and by precisely similar methods, and hence he could state positively that the highest wind pressure ever recorded at Holyhead was about 36 lbs. per square foot, corresponding to Mr. Curtis's 115 miles per hour, and about 20 lbs. would correspond to the gusts of 80 miles per hour. This was remarkable, since Holyhead was one of the windiest stations in the British Isles, yet pressures of 30 lbs. were quite common at many other stations inland, Bidston particularly, where 90 lbs. per square foot had been registered. He thought it was explained by the fact that the Bridled Anemometer was trustworthy, whereas the records of the pressure plates were utterly unreliable in so far as maximum pressure was concerned, on account of the unsatisfactory way in which the pencil was connected with the plate. Mr. Curtis had found that with an average or "normal' velocity of 40 miles per hour, a maximum of 80 or 90 might be expected in the gusts. At Oxshott he had found that the maximum was generally about double what Mr. Curtis called the normal velocity, and the relation seemed to hold for light as well as strong winds. It was noteworthy, however, that when the temperature was high the wind was always more gusty, also at Oxshott the South-south-west and North-west to North winds were especially gusty, but this was probably due to the fact that to the south-south-west and north-north-west there were trees within 100 yards nearly level with the anemometer, while in all other directions there was a very good exposure.

PROCEEDINGS AT THE MEETINGS OF THE SOCIETY.

May 16th, 1894.

Ordinary Meeting.

RICHARD INWARDS, F.R.A.S., President, in the Chair.

LEONARD BUCKELEY WILLIAMS, M.B., Ch.M., Hillsdon, Sidmouth, was balloted for and duly elected a Fellow of the Society.

The following communications were read:—

"THE RELATIVE FREQUENCY OF DIFFERENT VELOCITIES OF WIND." By WILLIAM ELLIS, F.R.S. (p. 287.)

"AUDIBILITY OF 'BIG BEN' AT WEST NORWOOD UNDER CERTAIN METEOROLOGICAL CONDITIONS." By W. MARRIOTT, F.R.Met.Soc. (p. 243.)

"EARTH TEMPERATURES AT CRONKBOURNE, ISLE OF MAN, 1880-1889." By A. W. MOORE, M.A. (p. 250.)

"NOTE ON A DUST WHIRL OR WHIRLWIND AT ADDISCOMBE, APRIL 22ND, 1894." By P. BICKNELL, F.R.Met.Soc.

ON Sunday, April 22nd, 1894, between 2.30 and 2.31 p.m., I, and two friends walking with me, saw a whirlwind or dust whirl close to Addiscombe Road Station.

It was calm, or almost calm, when we saw a sudden cloud of dust almost at the corner of Canning Road. The cloud collected opposite the railway station, and a thin column of dust ascended from that point to a height of 60 to 100 yards, at first perpendicularly, and then turning to the north. The lower part of the whirl, rotating with the sun, advanced along the Addiscombe Road for some 80 yards, then turning the corner of Canning Road and being lost to sight.

Any light breeze there was was from about East-south-east, but it was *very nearly* calm all round, and I particularly noticed that the leaves of the trees close to the course of the whirl were quite still.

The ascending dust looked just like yellow smoke rising from a chimney on a perfectly calm day, but, of course, it rose much higher.

Though I never saw such a phenomenon before, I presume it is of frequent occurrence.

MR. G. J. SYMONS, F.R.S., exhibited three lantern slides of SNOW CRYSTALS.

June 20th, 1894.

Ordinary Meeting.

RICHARD INWARDS, F.R.A.S., President, in the Chair.

The following communications were read:—

"FOGS REPORTED WITH STRONG WINDS DURING THE 15 YEARS 1876-90 IN THE BRITISH ISLES." By ROBERT H. SCOTT, F.R.S. (p. 253.)

"SOME CHARACTERISTIC FEATURES OF GALES AND STRONG WINDS. By R. H. CURTIS, F.R.Met.Soc. (p] 262.)

MR. R. H. SCOTT read the following:—

"NOTE ON TWO OCCURRENCES OF GLOBULAR LIGHTNING IN WARWICKSHIRE"

I HAVE received from my brother, Mr. E. A. Scott, M.A., one of the Masters of Rugby, a note stating that at about 11 a.m. on Thursday, April 26th, 1894, during a hailstorm, he saw a ball of fire "about as large as would go into a stable bucket" touch a tree close to his house at Rugby and explode. The lightning scathed the bark on both sides, "covering the road and one walk with outer bark (elm) stripped off."

Apparently this fire ball was not seen until immediately before its explosion.

The other occurrence took place on Sunday, July 2nd, 1893, at Dunchurch, near Rugby, and is described in *Nature*, Vol. XLVIII., at p. 341, in a letter from Mr. L. Cummings, M.A., another of the Rugby Masters. Mr. Cummings says, "I was enabled to examine four witnesses, all of whom agree that during an interval of two minutes before the explosion a large fiery globe was seen travelling through the air, and emitting light of such dazzling brilliancy that the only one of them who was out of doors at the time was for a moment blinded and dazed, and felt for some short time afterwards a sensation of pain in the back of the head and the neck.

"The path taken by the fireball during the two minutes it was observed could hardly have been direct, as the direction taken when first seen makes an obtuse angle with the direction indicated by all who saw it immediately before the explosion.

"The damage done was the fracture of 24 panes of glass in the house, and the breaking off, at a height of 17 feet from the ground, of the top of a Wellingtonia some 80 feet high, and distant 23 yards from the nearest corner of the house."

MR. R. H. SCOTT read the subjoined letter from a correspondent in the Philippine Islands on the subject of the dependence on atmospheric conditions of the motion of the smoke of volcanoes.

In the *Proceedings of the Royal Society*, Vol. XLIII., the Hon. R. Abercromby gives two sketches of the smoke column, (1) in fine weather, and (2) before a typhoon, of the "volcano of Abayon in the Island of Albay." This should read the "volcano of Mayon, near Albay, at the southern end of the Island of Luzon." The letter confirms, in the main, Mr. Abercromby's remarks.

"DEAR SIR,—My friend, Mr. F. E. Coney, has written me from England asking me to write you direct any information I could supply you with in regard to the smoke issuing from the volcano of Mayon. I can say nothing from personal observation, but two gentlemen here who lived at Tobaco, a town situated at the base of the mountain, inform me that during fine weather the smoke ascends straight. During, or rather before, bad weather, the smoke descends, forming a cap all round the summit, not only on one side as the sketch Mr. Coney sent me suggests. The distance which the smoke descends varies according to the density of the atmosphere. It is not necessary that a typhoon should follow; a strong blow from the South will cause this. Neither gentleman can state certainly that they have ever seen this "cap" half way down, but certainly quite one-third. But they think that before a heavy typhoon, with an abnormally low barometer, the mountain may be half covered.

"I trust this information will be of use to you. If there is any other information which you may require which I can obtain for you, please make use of my services.—I am, dear Sir, faithfully yours, D. M. FLEMING. Manila, 15th May, 1894."

CORRESPONDENCE AND NOTES.

Dew and Sea Breeze.—Mr. S. Knott, in a letter to Mr. R. H. Scott, F.R.S., dated Mojanga, Madagascar, July 24th, 1894, says: "When visiting you over a year ago you asked me if heavy dew brought rain, to which I replied in the negative. This season I have carefully watched the after effects of dew, and find that during the present monsoon (S.E.) heavy dew invariably brings a change of wind in the afternoon of the day following, or here a sea breeze from North-west to South-west; and, curiously, the heavier the dew the stronger the sea breeze. And further, during this monsoon I find that these heavy dews and sea breezes occur at the spring tides, and the monsoon is much lighter during these 12 days; but when the neaps take on it increases very much in force, and only varies from due South to South-east."

Rainfall at Sevenoaks.—Mr. W. W. Wagstaffe, having completed ten years' residence at Sevenoaks, has forwarded the following results of his rainfall observations:—

RAINFALL AT SEVENOAKS, 1884-93.

Years.	Jan. in.	Feb. in.	Mar. in.	April. in.	May. in.	June. in.	July. in.	Aug. in.	Sept. in.	Oct. in.	Nov. in.	Dec. in.	Total. in.
1884.....	2·48	1·95	1·93	1·63	·74	1·64	1·93	·93	4·97	1·74	·82	3·80	24·56
1885.....	2·12	3·03	1·65	2·50	3·88	1·29	·25	1·15	4·73	4·32	2·85	1·76	29·58
1886.....	3·21	·58	1·66	2·17	4·08	·54	2·77	1·64	2·59	2·77	4·24	4·28	30·44
1887.....	2·89	·52	1·68	2·43	2·00	1·26	·99	2·62	2·38	2·22	4·73	2·10	25·82
1888.....	·72	1·80	4·59	2·16	1·19	5·92	5·31	3·31	1·59	1·70	4·96	2·20	35·45
1889.....	1·22	3·23	2·54	2·20	3·00	1·90	2·60	2·65	1·55	6·10	1·56	2·19	31·74
1890.....	3·75	1·21	3·14	2·70	1·73	2·25	5·46	3·95	·72	1·37	3·53	·56	30 37
1891.....	3·34	.....	2·19	·72	3·76	1·84	4·52	4·51	1·69	7·70	2·98	4·36	37 61
1892.....	·86	1·65	2·07	2·07	1·17	5·40	2·55	3·96	2·82	5·94	4·16	2·67	35·34
1893.....	2·80	4·33	·73	·01	·46	·77	3·22	1·07	1·91	4·86	3·19	2·92	26·27
Means ...	2·34	1·83	2·22	1·96	2·20	2·28	2·96	2·57	2·49	3·87	3·30	2·68	30·70

The greatest fall on one day was 2·63 ins. on June 28th, 1892.

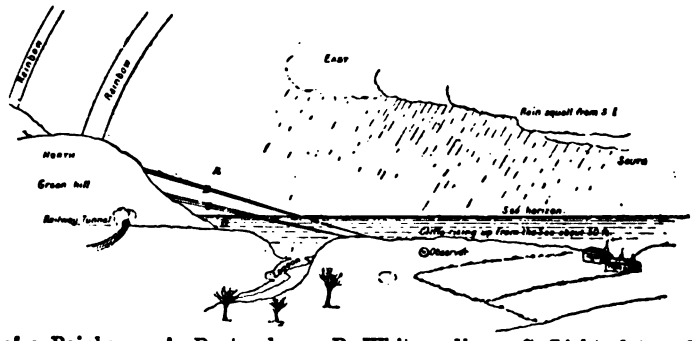
Mr. Wagstaffe recorded the rainfall twice daily, viz. at 10 a.m. and at sunset, with the view of seeing what an "invalid's day and night" would show in the difference of rainfall; the invalid's day being taken to be from 10 a.m. to sunset. The percentage of rain which fell in the former period, compared with that which fell in the latter period, was as follows:—

	Day	Night		Day	Night
January	37	63	July	48	52
February	39	61	August	42	58
March	35	65	September	37	63
April	38	62	October	42	58
May	40	60	November	35	65
June	43	57	December	41	59

[The division of the 24 hours into two periods, 10 a.m. to sunset and sunset to 10 a.m., may be interesting from the point of view of the valetudinarian, but it is otherwise an arbitrary and artificial division, one having no meteorological significance, and no relation with any physical fact, such as, for instance, would have been the case had the limiting times been sunrise and sunset. The varying percentages found for different months must largely depend on the difference in the length of the adopted day at different seasons, rather than on any real variation in the daily distribution of rainfall. So that the conclusions of the author have no meaning in a meteorological sense, as between day and night, but only as referring to the division of the day adopted.—ED.]

Radii to a Rainbow.—Mr. H. C. Russell, F.R.S., of the Sydney Observatory, New South Wales, has forwarded the accompanying sketch made by Mr. L.

Hargrave of two well-defined radii of a rainbow, which he observed at Stanwell Park, 20 miles south of Sydney, at 5 p.m. on May 9th, 1894. The radii remained visible for 10 minutes.



Radii of a Rainbow. A. Dust colour. B. White radius. C. Light slate coloured radius. D. Dark slate colour.

Protection from Lightning.—The U.S. Weather Bureau has issued a pamphlet on this subject by Mr. A. McAdie, which is intended to furnish information of practical value to all classes, and especially to farmers, builders, and physicians. The author gives statistics of deaths, fires, and damage caused by lightning, and shows that barns, granaries, and stables are the objects most frequently struck. The risk in the country is about five times greater than in the city. With regard to trees, the oak is most frequently, and the beech least frequently struck. The author mentions various methods recommended for protection from lightning, and describes the *Report of the Lightning Rod Conference* as an excellent one, and that it must stand for years as the embodiment of the most widely gathered information and well considered decisions. Mr. McAdie points out that there are some very prevalent misapprehensions with regard to lightning. For example: that it never strikes twice in the same place; that the most exposed place is always struck; that a few inches of glass or a few feet of air will serve as a competent insulator to bar the progress of a flash that has forced its way through a thousand feet of air, &c. The author then proceeds to give some practical rules for guidance in selecting and maintaining lightning conductors, the last of which is as follows:—"Finally, if you should be in the vicinity of a person who has just been struck by lightning, no matter if the person struck appears to be dead, go to work at once and try to restore consciousness. There are many cases on record proving the wisdom of this course; and there is reason for believing that lightning often brings about suspended animation rather than somatic death. Try to stimulate the respiration and circulation. Do not cease in the effort to restore animation in less than one hour's time."

Remarkable Hail.—During a severe hailstorm at Vicksburg on the afternoon of Friday, May 11th, a remarkably large hailstone was found to have a solid nucleus, consisting of a piece of alabaster from one-half to three-quarters of an inch. During the same storm, at Borina, 8 miles east of Vicksburg, a gopher turtle, 6 by 8 inches, and entirely encased in ice, fell with the hail.

An examination of the weather map shows that these hailstorms occurred on the south side of a region of cold Northerly winds, and were but a small portion of a series of similar storms; apparently some special local whirls or gusts carried heavy objects from the earth's surface up to the cloud region, where they were encased by successive layers of snow and ice, until they fell as hailstones. The fact that hailstones, as well as drops of water and flakes of snow, often contain nuclei that must have been carried up from the earth's surface, is entirely in accord with the general principle that ascending currents precede the formation of cloud and rain, and that solid nuclei are needed to initiate the ordinary precipitation of moisture.—*Monthly Weather Review*, May 1894.

The Weight of Snow.—Prof. Cleveland Abbe, in the *Monthly Weather Review* for April, gives the following notes on the weight of snow:—"In connection with the heavy snowfall of April 10th and 14th, in Pennsylvania, N. 41°, W. 77° 40′, the amount of snow that fell on the platform scales at that place weighed 1,640 pounds; as the platform was 8 by 12 feet, or 96 square feet in area, this gives an average weight of about 17 pounds to a square foot, which is equivalent to a depth of 3·3 inches of water, and using the ordinary ratio, 10, this gives a corresponding depth of 33 inches of snow.

"Mr. Edward Ferry, of Bel Air, Harford Co., Md., in a letter published in the monthly report of the Maryland State Weather Service, states that his clerk found that the weight of the snow on the platform scales at that place was 1,520 pounds (presumably on the morning of April 12th); the scale platform measured 7 feet 10 inches by 15 feet; this gives an average of 12·93 pounds to the square foot, and, if we assume that none of the snow melted, and so escaped being weighed, this would correspond to a depth of 2·4 inches of water. The average depth of snow lying on the ground at the end of the great snowstorm of April 10th and 11th, in Northern Maryland, varied from 15 to 30 inches in the different localities covered by newspaper reports, but the largest recorded by regular observers was 24 inches at Darlington and at Fallston, both in Harford County, at the head of Chesapeake Bay.

"Although the above result may be rather crude, yet it suggests an excellent method of getting at the average quantity of precipitation in case the snow falls without melting and without much drifting. It also gives some idea of the weight that must be supported by roofs and walls in cases of similar heavy snowfalls.

Climate of Algeria.—Mr. A. S. White, in a paper on "The Situation in Algeria" (*Scottish Geographical Magazine*, April 1894), gives a brief account of its climate. The paper is admirably illustrated by maps showing the vegetation and surface features; orographical features; mean annual temperature; and mean annual rainfall. The climate and vegetation of Algeria approximate to those of southern Europe, but are more sub-tropical in character. The average annual rainfall of Algeria is sometimes taken at 29 ins. The highest rainfall (over 31 ins.) is recorded in the Jujura mountains, to the east of Algiers; the lowest, of course, in the Desert. The intervening regions receive, roughly, from 28 to 31 ins. on the northern slopes of the Atlas, and from 15 to 23 ins. on the southern slopes. On the borderland of the Desert there is an annual rainfall of from 7 to 15 ins. Algeria suffers very much by the absence of important rivers, and the prolonged drought in the summer; but extensive irrigation works (costing nearly five millions of francs) have been undertaken to remedy these defects, whilst in the south especially at the base of the mountains, there are inexhaustible supplies of subterranean waters. Coinciding with the systems of climate, there are well marked and diversified characteristics of soil. Broadly speaking there are three distinctive regions: the *Tell* lands of the Littoral, the High Plateau, and the Saharan or Desert tracts. The vine, cereals, olives and oranges are cultivated in the *Tell*, cereals and *alfa* are raised on the High Plateau; and in the Desert regions date-palms and fruit trees bear fruit in the summer, whilst in the winter flocks and herds occupy the attention of the inhabitants.

Observations on Mount Ontake, Japan.—A party of observers set out in July 1891 from the Tokio Observatory to make a series of two-hourly observations on the summit and at the base of Mount Ontake, which is one of the highest mountains in Japan, being 10,023 feet above sea level. The observations extended from August 1st to September 12th, a period of 43 days. The results are published in the *Annual Report* of the Central Meteorological Observatory of Japan for 1891, part II. The mean atmospheric pressure on the summit during this period was 20·94 ins., which is only seven-tenths of that at sea level. The slightest labour soon caused fatigue, and breathing was greatly accelerated. The mean temperature of the air, though it was the hottest season of the year, was only 48°, which corresponds to the latter part of March or the middle of November in Tokio. Towards the end of August water, kept in a

tank placed outside the cottage, froze to a thickness of about 0·24 in. This, however, was said to be an unusual occurrence at this season; the minimum temperature on the 27th was 47° even at Kurosawa, the lower station (2,733 feet above sea level). As it is so cold on the summit great masses of snow remain unmelted in several shaded places even during midsummer. When clear days continued for a long time, as was the case in the first part of September, the temperature of the air generally rose above 68° by day, and even at night it remained above 41°. Anyone who exposed himself on such days to the direct sunshine felt its scorching effect upon the skin to be almost intolerable, owing to the great rarefaction of the atmosphere and the smallness of the amount of aqueous vapour in it.

When an area of low barometer passes near the mountain, the summit is enveloped in dense clouds with heavy wind and cold rain, which carry off the heat from the human body very quickly. In such cases climbers often lose their way, and are sometimes chilled to death.

During the period in question the temperature of the air during the days of storms remained almost stationary at 48° or little above, when the cold was felt to be more intense than in the calm dry days with lower temperature.

Climate of Alaska.—Mr. J. C. Russell, in a paper on "Alaska: its physical geography," in the *Scottish Geographical Magazine* for August, says that the climate of Alaska, like its physical features, presents marked contrasts. On the south coast the rainfall is excessive, amounting in some observed instances to more than 100 inches a year. A series of observations made at Sitka by Russian observers for 20 years gave a mean annual precipitation of over 83 inches. A belt of extreme humidity extends westward along the coast, probably increasing in breadth until Mount St. Elias is reached, and then diminishing in the vicinity of the Aleutian Islands. In the interior it is much drier, as is known from the experience of travellers, and also from a limited number of observations. At Camp Davidson, where the Yukon crosses the 141st meridian, as observed by Mr. M'Grath, of the U.S. Coast and Geodetic Survey, the precipitation from September 14, 1889, to June 22, 1891, was but 19·05 ins.; for the year 1890 it was 13·55 ins. On the northern coast, in common with other portions of the Arctic zone, the annual precipitation is small; at Point Barrow, as observed by the International Polar Expedition in charge of Lieutenant Ray, the rainfall for 1882 was a little over 8 inches.

The aridness of the interior and northern portion of Alaska may thus be compared with that of the arid region between the Rocky Mountains and the Sierra Nevada. The humid region along the south coast is a continuation of the rainy belt of Oregon and Washington. The excessive rainfall on the southern coast is accompanied by cool summers and by remarkably mild winters. The mean annual temperature at Juneau and Sitka is about 50°. The temperature seldom falls below zero (0°). The winters are milder than at Chicago or Boston, and are not marked by the extremes experienced in New York or Washington. In the interior the summers are warm, and occasionally the temperature rises to between 90° and 100° in the shade; but in winter the cold is excessive, and a temperature 40° or 50° below freezing point is frequently experienced for many days in succession. The difference in climate between the coast and the interior is, perhaps, most strongly indicated by the character of the vegetation. On the east coast of Mount St. Elias the forests are dense, the trees are large, and the undergrowth nearly as impenetrable as in the Tropics. In the interior the forests are almost entirely of spruce trees of small growth, which are confined to the river valleys, while the hill tops and mountain sides are bare of trees and covered with luxuriant grasses.

The marked climatic differences between the coast and the interior also find expression in the distribution of the glaciers, which are of great extent among the mountains on the coast, but are entirely wanting on elevations 4,000 to 5,000 feet high, situated near and even north of the Arctic circle.

RECENT PUBLICATIONS.

American Meteorological Journal. A Monthly Review of Meteorology. July-September 1894. Vol. XI. Nos. 3-5. 8vo.

The principal articles are:—Changes in the definitions of clouds since Howard: by H. H. Clayton (14 pp.) By following the changes in cloud nomenclature since Howard, the author says that it seems clear that there has been a gradual evolution during which differences and distinctions not recognised by Howard have been established, and errors due to perspective, as in the case of the cumulo-stratus, have been corrected. Thus a distinction between high and low cirro-stratus and high and low cirro-cumulus has been established, and the lower forms called alto-stratus and alto-cumulus. The stratus has been separated into fog and low sheet clouds, and two distinct forms of rain cloud recognised.—The newspaper weather maps of the United States: by R. de C. Ward (11 pp.).—Psychrometer studies: by Prof. H. A. Hazen (4 pp.).—Frequency of amounts of precipitation: by Prof. M. W. Harrington (12 pp.).—Precipitation and temperature and their effects on crop production in Texas for the year 1893: by Dr. I. M. Cline (9 pp.).—On cloud formation: by Prof. W. von Bezold (19 pp. and 2 plates). This is a translation of an address delivered in Berlin in November 1893, and published in *Himmel und Erde*, Vol. VI. No. 5.—Summer hot winds on the great plains: by Dr. I. M. Cline (12 pp.). Apparently the conditions on which the development of hot, dry winds over the eastern slope of the Rocky Mountains and eastward depends are the presence of nearly stationary or slow moving low pressure areas along the eastern slope and then eastward, with a relatively high pressure over the Pacific off the coast of Oregon or in that vicinity. In no instances are hot winds noted with a low pressure area which moves eastward with any degree of rapidity.—The Meteorological Services of South America: by A. L. Rotch (5 pp.). This is the first of a series of papers in which the author proposes to give an account of the meteorological services in the South American States based on a personal inspection in 1893. In the present paper he deals with Peru, Chili, and the Falkland Islands. In previous numbers Mr. Rotch has given similar notices of several of the European Weather Services.

Annuaire de la Société Météorologique de France. December 1893-March 1894. 4to.

The principal articles are: Résumé des observations centralisées par le Service hydrométrique du bassin de la Seine, pendant l'année 1892: par M. Babinet (35 pp.).—Note sur l'ouragan de Maisons-Laffitte, le 21 Septembre 1893: par G. Raymond (8 pp.).—Sur les observations pluviométriques de M. le Dr. Bérigny à Versailles (Seine et Oise): par V. Raulin (3pp.).—La pluie à Aragorri: par A. Angot (3 pp.).

Journal of the Scottish Meteorological Society. Third Series. No. X. 8vo. 1894.

Contains:—The monthly and annual Rainfall of Scotland, 1866 to 1890: by Dr. Buchan (22 pp. and 13 plates). Tables and maps are given, showing the mean monthly and annual rainfall at 324 stations for the 25 years. It is pointed out that the three prominent causes which determine the amount of the rainfall are the rise and fall of the temperature with season, the prevailing winds, and the physical configuration of the country with reference to these winds.—The Climate of Braemar: by R. C. Mossman (17 pp.). This is a discussion of observations extending over a period of 38 years, 1856-1893. The station, which is 1,111 feet above sea level, was founded in 1855 by H.R.H. the late Prince Consort.—Hygrometric researches at the Ben Nevis Observatory: by A. J. Herbertson (8 pp.). These researches were undertaken with the view of determining the amount of water vapour in the air under varying conditions. The gravimetrical method was adopted

of measuring the quantity of water vapour in the atmosphere by drawing a known volume of air through drying tubes, weighed previously to and after each experiment; and, at the same time, the ordinary dry- and wet-bulb thermometers were read at regular intervals, and also the general weather conditions noted. As regards the tabulation of dew points, vapour pressures, and relative humidities at the Ben Nevis Observatory, where the mean annual temperature is 30°·9, it seems certain that, for all temperatures about or below the mean, tables based on Regnault's formulæ give much truer values than those based on Glaisher's factors.—Comparison of observations at the low level Observatory, and at the Public School, Fort William: by R. T. Omond (6 pp.).

Meteorologische Zeitschrift. Redigirt von Dr. J. HANN und Dr. G. HELLMANN. June-September 1894. 4to.

The principal contents are:—Ueber den grossen Staubfall in Schweden und angrenzenden Ländern am 3. Mai 1892: von A. E. Nordenskiöld (18 pp.). On this day a fall of dust occurred over a narrow strip of country extending from Finland to the mouth of the Elbe. The dust was distinctly granular, and analysis showed that its main constituents were:—

	Per cent.
Silica	58
Alumina	13
Loss on Combustion (carbonaceous matter)	15
	86

Baron Nordenskiöld cites numerous other dust-falls, and gives analyses of dust collected from crevices in steeples and other rarely visited elevated localities. He concludes, as the result of the whole inquiry, that the earth is encircled by a cloud-ring composed of matter in a great measure silicious. Some of the dust-falls are distinctly volcanic, but that under consideration was not so. In the case of the Atlantic dust-falls there is a large admixture of local terrestrial dust with this cosmical dust, but in higher latitudes the cosmical dust comes down unadulterated. The phenomena of the zodiacal light are, according to the author, evidently related to the dust-ring.—Ueber die Anwendung der Photogrammeter zur Messung von Wolkenhöhen: von P. Åkerblom (6 pp.). This a description of a double camera fitted on a theodolite intended for the production of photographs of the same part of a cloud from the extremities of a base-line, with formulæ for calculation of the resulting heights and velocities. —Die Gewitter und der Wettersturz am 4. September 1892 in den Ostalpen: von K. Prohaska (11 pp.). This is an account of the most important development of thunderstorms which has been noticed in Carinthia since observations of such phenomena have been organised there in 1885. Dr. Prohaska argues for the existence of a strong inclination of the axis of a depression which accompanied the storms, and gives two isobaric charts for the same hour, one at sea level, the other at the level of 3,000 metres, the latter showing the centre of the depression shifted nearly 90 miles to the north. The discussion of the effect of this as regards descending movements in front of an advancing depression, and ascending in its rear, will well repay perusal.—Die tägliche Periode der Richtung (und Geschwindigkeit) des Windes auf dem Eiffel-Thurm: von Dr. A. Sprung (11 pp.). The author has dealt not only with the direction but also with the velocity of the wind for two full years. As regards the latter, the velocity at the base has its maximum between noon and 2 p.m. throughout the year, but on the top the minimum falls during the day hours, and its time varies through five hours, falling at 9 a.m. in summer and at 2 p.m. in winter. As regards direction there is strongly marked backing in the forenoon and veering in the afternoon. In winter the changes are not so decided, but falling in with the change in the hour of minimum velocity. Dr. Sprung concludes the paper by saying that the level of the station was still rather low, but that the results give a general support to the theory of vertical changes propounded by Espy and Köppen.—Die Resultate der meteorologischen Beobachtungen auf dem Pic du Midi: von Dr. F. Klengel (20 pp.). This paper has

extended over three numbers of the *Zeitschrift*. The author's conclusions are: 1. The climate is about 4° warmer than the Western Alps, and about 5° warmer than the Eastern Alps at the same level. This is due to its lower latitude. 2. The annual range of temperature at the summit is very great. 3. The chief features of the Pyrenean climate are the cold spring and the great contrast between spring and autumn. 4. April is especially cold, owing to the fact that in that month the track of Atlantic depressions comes near. 5. The absolute minima appear very abnormal. The mean and absolute maxima are very high. 6. The non-periodic temperature oscillations are very great at the summit. 7. The yearly period of pressure is chiefly marked by the depression of April. 8. The diurnal amplitude of pressure appears very large in comparison with Alpine stations. 9. As to rain, a maximum at between 7,500 and 7,900 feet is clearly marked.—Prof. C. Marangoni über den Hagel (10 pp.). This communication is a translation by Dr. J. M. Pernter of papers in the *Atti della R. Acad. dei Lincei* for 1893 and 1894. The author goes back to Volta's original explanation of hail formation, and he points out that if we make allowance for Volta's ignorance of modern thermal and electrical discoveries, we must admit that he showed—1. That the cold was due to evaporation; 2. That the cause of growth of the hailstones is electrical repulsion and attraction; and 3. That electricity is not the primary cause of the hail, but its result and a secondary cause. The other papers deal with the shapes of the hailstones, the repulsion of the stones in the cloud, and the peculiar noise of hail showers.—Beiträge zur Theorie des Ventilations-Pyschrometers: von W. A. Nippoldt (17 pp.). This is an elaborate discussion of the principle on which the Hygrometrical Tables in general use are based, especially with reference to the recent proposals of Dr. Ekholm as regards the formula for hygrometrical reductions below the freezing point. The author discusses the works of Chistoni, Pernter, Sworykin and others on the same subject, and the paper well merits study from those interested in the question.—Die Anticyklonen des Winters 1893-94, nach Beobachtungen auf dem Brockengipfel (1142 m.): von R. Süring (8 pp.). The author remained on the top of the Brocken for some months, in order to ascertain the advisability of erecting an observatory there. The paper gives an account of his results during the anticyclone of that winter, and he comes to the conclusion that the frequent rises of temperature which are observed are due mainly to the descending currents of air, and so probably to a sort of *föhn* action.

Proceedings of the Royal Society. Vol. LVI. No. 336. 8vo. 1894.

On the electrification of air: by Lord Kelvin and M. Maclean (10 pp.). The authors describe some experiments which they made to find if a small unchanged portion of air could be electrified sufficiently to show its electrification by ordinary tests, and could keep its electrification for any considerable time; and to test whether or not dust in the air is essential to whatever of electrification might be observed in such circumstances, or is much concerned in it. From the experiments it is seen that, on the supposition of electric density uniform throughout the spherical enclosure, each cubic centimetre of air experiences an electrostatic force towards the boundary in simple proportion to distance from the centre, and amounting at the boundary to nearly 10 per cent. of the force of gravity upon it; and electric forces of not very dissimilar magnitudes must have acted on the air electrified as it actually was in the non-spherical enclosure used in the experiments. If natural air or cloud, close to the ground or in the lower regions of the earth's atmosphere, is ever, as in all probability it often is, electrified to as great a degree of electric density as the authors have found it within their experimental vat, the natural electrostatic force in the atmosphere, due, as it is, no doubt, to positive electricity in very high regions, must exercise an important ponderomotive force quite comparable in magnitude with that due to difference of temperatures in different positions. It is interesting to remark that negatively electrified air over negatively electrified ground, and with non-electrified air above it in an absolute calm would be in unstable equilibrium; and the negatively electrified air would therefore rise, probably in large masses, through the non-electrified air up to the higher regions, where the positive electrification is supposed to reside. Even with no stronger electrification than that which

the authors have had within their experimental vat, the moving forces would be sufficient to produce instability comparable with that of air warmed by the ground and rising through colder air above. During a thunderstorm the electrification of air, or of air and the watery spherules constituting cloud, need not be enormously stronger than that found in the experiments. This is seen by considering that if a uniformly electrified globe of a metre diameter produces a difference of potential of 88 volts between its surface and centre, a globe of a kilometre diameter, electrified to the same electric density, reckoned according to the total electricity in any small volume (electricity of air and of spherules of water, if there are any in it), would produce a difference of potential of 88 million volts between its surface and centre. In a thunderstorm, flashes of lightning show us differences of potentials of millions of volts, but not perhaps of many times 88 million volts between places of the atmosphere distant from one another by half a kilometre.—On rapid variations of atmospheric temperature, especially during Föhn, and the methods of observing them: by J. Y. Buchanan, F.R.S. (20 pp.). It has not been before remarked that the true Föhn occurs in our own country, and with its characteristics quite as well marked as in Switzerland. It is sometimes supposed that a great absolute height of mountain chain is required for its production; but this is not so. A relative height of 3,300 to 3,950 feet is quite sufficient for its production; and this is equally available on the west coast of Scotland and on the northern slopes of the Alps. The author describes some observations which he made in the summer of 1893, which was abnormally warm all over the north of Europe. In the beginning of July he observed the Föhn at Fort William, and in the latter part of August in the Upper Engadin, and more particularly in the valley occupied by the Morteratsch glacier. Besides the observation of the varying temperature of the air itself, the investigation of the temperature gradient set up between the melting ice surface of the glacier and the hot winds blowing over it presented considerable interest. The curious fact was observed that while the hot wind was blowing over the glacier and melting the surface in abundance, the temperature of the air, as close to the ice as a thermometer could be applied without touching the ice, was never lower than 41°·9.

Sitzungsberichte der kaiserlichen Akademie der Wissenschaften in Wien. Mathem.-naturw. classe: Band CIII. Abth. II. January 1894. 8vo.

Contains: Beiträge zum täglichen Gange der meteorologische Elemente in den höheren Luftschichten: von J. Hann (48 pp.). This is a discussion of the results of two different mountain stations, Ontake (10,023 feet) in Japan and Mont Blanc (15,878 feet), M. Vallot's observations. The observations of pressure and temperature are discussed with great care, and from almost every point of view that is possible, and each result is compared with those given by Dr. Hann in his previous communications on similar subjects. The final outcome is thus stated: "The results of the pressure observations at the summit of Mont Blanc are in complete accordance with those at other summit stations, and also on the Eiffel Tower, and they all indicate that in the upper strata of the free atmosphere the daily range of temperature is much less than what is shown by direct temperature observations."

Symons's Monthly Meteorological Magazine. July-September 1894. Vol. XXIX. Nos. 342-344. 8vo.

Contains: The May frost of 1894 (7 pp.).—Sun spots and air temperature (1 p.).—The Antwerp Congress (1 p.).—Rainfall and flood at Bristol (2 pp.). This occurred on July 24th, when 2·53 ins. of rain fell in ten hours and a half. —Heavy rain and hailstorms, July 1894 (2 pp.).—Rain of July 1894 in the South-east of England (1 p.). The total for the month was considerably more than twice the average.—The British Association at Oxford (11 pp.). This gives notes of some of the meteorological papers read in the various sections.

Transactions of the South African Philosophical Society. Vol. V. Part II. 1886-1889. 8vo. 1893.

Contains: The winter storms of South Africa, illustrating the value of Cape

Point as a warning station: by A. G. Howard (16 pp. and plate). Cape Point is a peak standing up about 816 feet above sea level, and in the author's opinion offers itself as an indicator of coming storms to those who will take the trouble to investigate what its warnings portend.—The Storms of South Africa: by A. G. Howard (12 pp.).—The barometer: its reduction to sea-level: by A. G. Howard (7 pp.).—On some photographs of lightning flashes: by C. R. Woods (6 pp.).—Sea-levels in South Africa from barometric observations: by F. Guthrie (8 pp.).—The relation of the sand dune formation on the South-West Coast of Africa to the local wind changes: by H. C. Wilmer (4 pp.).

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THE END.

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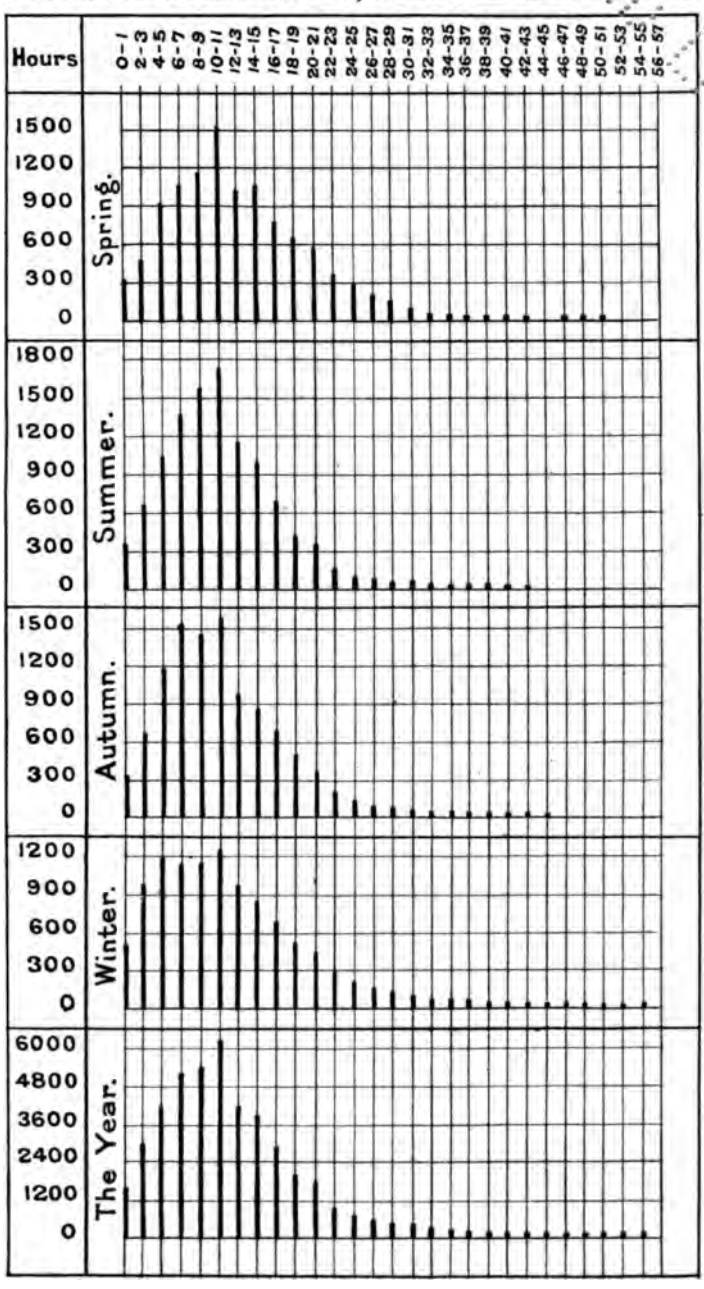

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